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Residual Waste Management Phase I Report

Ventura Regional County Sanitation District, CA

Prepared for

Robert S Kerr Environmental Research Lab, Ada, OK Source Management Branch

Feb 80

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The project report presents the economic, social, and environmental analysis regarding alternative plans for the handling and disposal of residual organic waste in Ventura County. Waste quantities from municipal treatment plants, livestock operations, agricultural operations and meat and fish processes were inventoried as part of the study. An apparent best alternative was selected using the data which recommends using a leased centralized trucking system to haul all wastewater treatment plant sludges in Ventura County to suitable landfill disposal sites. The selection of the alternative method is heavily dependent upon implemation of sludge disposal guidelines.

The present method of handling agricultural wastes was considered adequate.

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RESIDUAL WASTE MANAGEMENT
PHASE I REPORT

by

Ventura Regional County
Sanitation District
Ventura, California 93001

Grant No. S803223-01-0

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in ground water; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control, or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American public.

William C. Galegar

W. C. Galegar
Director
Robert S. Kerr Environmental Research Laboratory

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ABSTRACT

Alternative management, handling, treatment and disposal schemes for residual wastes generated by industrial, municipal and agricultural operations within Ventura County were evaluated. Residual wastes are wastes which cannot be properly discharged to a municipal wastewater system.

In addition, digested municipal wastewater sludges were included with organic residual wastes generated within the county. Alternatives considered included: (1) centralized regional facility for treatment; (2) use of landfill; (3) centralized trucking of organic solid waste; and (4) "no project" for organic solid waste.

This research project includes preliminary planning, treatability studies of select residual industrial wastes, development of proposed treatment processes and management schemes, preparation of construction plans and specifications, and operation of the facility for a one-year period after it is constructed and on-line. Phase I, which includes preliminary planning, treatability studies and development of proposed treatment processes and management schemes, has been completed. This report documents the work completed during Phase I.

A detailed industrial waste survey, including on-site inspection, was conducted to define potential users and project what residual materials should be treated at this facility. The survey results, including type and quantity of waste from typical industries, have been compiled. Wastes were grouped into five categories (oily wastes, brines, metallic wastes, nonmetallic toxins, and organic wastes) and treatment and/or management schemes were proposed for each. Bench-scale models of selected unit processes were assembled and treatability studies conducted on actual wastes from each category except for organic wastes. Operational and design parameters were defined for each of the proposed treatment schemes.

Cost estimates including operation and maintenance costs were prepared for each treatment or management scheme.

Additionally, due to the environmental impact potential of alternative organic wastes handling and disposal schemes, a project alternative analysis was made considering such impacts.

This report was submitted in fulfillment of Grant No. S803223-01-0 by the Ventura Regional County Sanitation District under the sponsorship of the U.S. Environmental Protection Agency. This work covers the period January 1, 1975, to February 1978 and work was completed as of February 15, 1978.

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SECTION 1

INTRODUCTION

PROJECT LOCATION

The Ventura Regional County Sanitation District is located in Ventura County, northern neighbor of Los Angeles County in Southern California. Reference is made to Figure 1, Vicinity and Location Map. The boundaries of the Regional District are coterminous with those of Ventura County and include an area of 1,800 square miles and a population of 450,000. The northern half of the county is in the Los Padres National Forest and is characterized by rugged. mountainous terrain where elevations range to 8,900 feet. Alluvial valleys and gently sloping terrain predominate in the southern and western part of the county. The coastal portion of the county is relatively flat and contains most of the agricultural, housing, and industrial activities.

The coastal, alluvial valleys and rolling hills which comprise the southern area, together with the Mediterranean climate, high percentage of sunshine, and concentration of rainfall in the winter months, combine to make agriculture the largest income producing industry. Over 45,000 acres are devoted to row crops such as lettuce, celery, tomatoes, beans and cauliflower. Tree fruit and nut crops cover 60,000 acres and the area produces over 60 percent of the nation's lemon supply. Oil production is the second largest industry in Ventura County with general manufacturing and support industries also being prevalent.. Specific industrial activities consist of citrus and vegetable packing, meat and fish processing, chemical suppliers, ferrous and nonferrous metal works, aircraft support industries, paper products, and typical support industries found in most urban area.

The population of Ventura County is divided among nine incorporated cities, the largest of which is Oxnard with a population of approximately 90,000. The population centers of the county are not characterized by urban sprawl, but rather are separated by areas of agricultural lands and open space areas. Urban areas comprise less than 5 percent of the land area or about 55,000 acreas. The oil field activities in the county are centered in the western portion of the county to the north and west of the City of Ventura. Industrial activities are spread among the various cities depending upon their size. Currently, 5,000 acreas are devoted to industrial activities with nearly 18,500 acres planned or zoned for future industrial use. The historically rural setting of Ventura County is starting to disappear as development pressures from the Los Angeles are beginning to locate in and among the nine incorporated cities of the county, requiring greater planning and awareness of their disposal needs.

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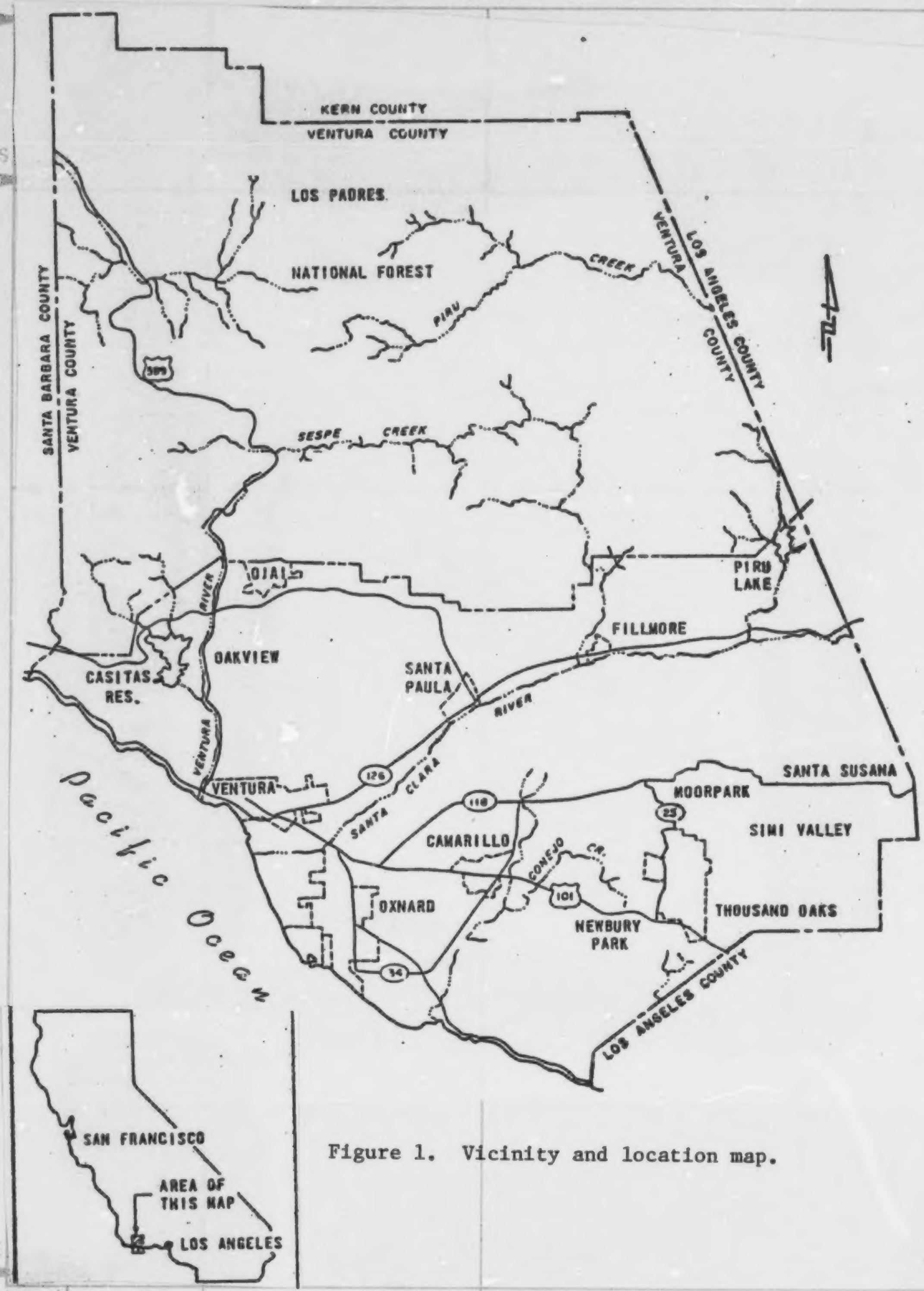
KERN COUNTY
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LOS PADRES
NATIONAL FOREST
SANTA BARBARA COUNTY
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VENTURA COUNTY
LOS ANGELES COUNTY
PIRU
CREEK
SESPE
CREEK
33
OJAI
VENTURA RIVER
CASITAS RES.
OAKVIEW
SANTA PAULA
FILLMORE
PIRU LAKE
RIVER
126
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Pacific Ocean
VENTURA
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MOORPARK
SANTA SUSANA
23
SIMI VALLEY
CAMARILLO
CONEJO CR.
101
OXNARD
NEWBURY PARK
THOUSAND OAKS
34
LOS ANGELES COUNTY
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Figure 1. Vicinity and location map.

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PROJECT BACKGROUND

Implementation of Public Law 92-500 requires that industires and certain agricultural operations within the United States provide source control and pretreatment necessary to severely limit the amount of hazardous and/or noncampatible pollutants discharged to the environment or into municipal systems. Noncompatible pollutants are not amenable to municipal treatment and frequently prohibited from discharge into a municipal collection system. The resulting process modifications and pretreatment lead to generation of residual waste products that must either be given further treatment or disposed of residual wastes has been that of discharge to Class 1 landfill sites. Class 1 sites refer to those underlined with an impermeable membrane to eliminate the possibility of leaching toxic materials into groundwater. In view of the limited number and size of such sites and the costs of operating them, it is essential that alternative means of disposing residual wastes be developed.

The purpose of this project is to explore and demonstrate the effectiveness of a centralized residual waste treatment facility which can adequately accept and dispose of these pretreatment residues. Such a facility could provide treatment of hazardous and/or noncompatible residual wastes rather than resorting to practices such as landfilling, deep well injection or indiscriminate discharge into the environment as primary methods of disposal.

The proposed residual waste treatment facility will consist of selected treatment schemes which have been shown to be feasible for treating different types of wastes. Technology will be demonstrated by determining the best operating techniques, process efficiencies, and treatment economics for each classification of residual wastes. The type of treatment facilities demonstrated will be suitable for use in other areas of the country, and the constructed treatment system can serve as a pilot project for major population areas such as the Los Angeles region. After completion of the demonstration project, the facilities will be used to provide an ongoing program of residual waste treatment and disposal.

In order to establish the feasibility of properly managing wastes at a central treatment facility, the Ventura Regional County Sanitation District prepared "a proposal for construction of a residual waste treatment facility" and submitted it to EPA for federal financial assistance. The proposal stated that the "objective of this project is to demonstrate the most effective technology for management of a regional facility which will have the capability of treating and disposing of the residual wastes emanating from industrial, agricultural, and domestic activities within the Ventura Regional County Sanitation District." The EPA approved the proposal and provided a research and demonstration project grant to support the program. Work contained in the grant authorization consists of the following three phases.

Phase 1 - Primary Planning and Pilot Plant Studies

The preliminary planning work requires development of the research plan outline, identification of the final treatment process system, and final preparation of a total project budget. Pilot plant studies may be required

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on items identified in the preliminary planning stage. The pilot plant studies would involve the preparation of a testing program, laboratory analysis, and report recommendations.

Phase II - Facilities Design

Phase II involves the development of design criteria and preparation of construction plans and specifications.

Phase III - Facilities Operation

Operation of the facilities will determine the best methods for regional waste management and economics of treating the classes of wastes identified in Phase I. The final report will consider and evaluate: (1) economics, (2) residual treatment management, (3) local community interaction with the facilities, (4) interaction of local industries with the facilities, (5) a closed-cycle treatment of residuals, (6) projections of residuals produced within the service area, and (7) the impact of pollution control.

The purpose of this report is to present the findings of Phase I. A summary of this work is presented below.

PHASE I SUMMARY

Phase I work began with a detailed residual waste survey to further define types and amounts of residual wastes generated within Ventura County. The survey, which included on-site inspections, projected the amounts and quantities of wastes that might be expected at a central residual waste treatment facility. It was found that the types of residual wastes originating in Ventura County are quite diverse. Food processing, chemical, agricultural, petroleum, paper processing, manufacuring, animal and domestic residuals are generated daily within the region. These residual wastes were classified into general categories which contain wastes of similar chacterisitics so that they can be treated in a common treatment scheme. The five categories are brine wastes, organic wastes, toxic metal wastes, nonmetallic toxic wastes, and residual petroleum wastes (oily wastes).

The second major effort under Phase I consisted of a preliminary planning step for development of alternative treatment and/or disposal schemes for each waste category on the basis of process knowledge and literature reference work. A recommended project for further bench-scale testing was presented. It became evident at this point that the work required for the organic waste category was much more detailed than for the other four waste categories; therefore, studies on the organic waste group were segregated from those related to the other four waste categories.

A testing program was devised for the four waste categories that were ready for treatability studies. The objectives of the bench-scale testing program (BSTP) were to demonstrate the effectiveness of the proposed treatment schemes on Ventura County wastes and to establish design criteria for treatment facilities. The extensive research effort included sampling of

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actual residual wastes from various industries throughout the county. The samples were transported to the laboratory where they were characterized and treated using the treatment schemes proposed in the earlier planning step. Based on these tests, a finalized treatment scheme for each of the four waste categories was developed and design criteria were presented. Cost estimates were prepared for facility construction, operation and maintenance.

Alternative treatment, handling and/or disposal schemes were developed for "problem" organic solid wastes. Problem solids are those which are not presently handled in a beneficial manner. All sewage sludges are considered to be problem solids based on the assumption that the presently drafted regulations concerning sludge disposal will be issued. There will probably need to be an alternate means for disposing of these sludge solids in the near future.

Problem waste also includes a percentage of vegetable and fruit processing waste solids that are not currently being recycled or marketed. Of the two waste solids, the municipal wastewater treatment plant sludges are considered to be the most significant problem because of the greater quantities and health risks present.

The alternative approaches include structural and non-structural schemes. Structural alternatives include treatment facilities while non-structual alternatives include trucking to landfill and "no project." Environmental impacts were identified and quantified to assist in the selection of the best alternative. Cost estimates were prepared for both structural and non-structural schemes.

By segregating the organic waste category from the other four waste categories, the residual waste study is basically separated into a residual "solid" (organic) waste study and residual "liquid" waste study. To simplify their presentation, each will be discussed in separate sections of this report.

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SECTION 2

CONCLUSIONS

BENCH-SCALE TESTING PROGRAM

The bench-scale testing program evaluated residual wastes from a variety of industies in Ventura County which generated toxic metal waste streams, nonmetallic toxic wastes, oily wastes and brine wastes. The following basic unit processes were used in the study of each sample as appropriate: cyanide oxidation, chromate reduction, ammonia removal, heavy metal precipitation, carboxylic acid ion exchange, foam fractionation-flotation, filtration, carbon absorption, sludge dewatering/thickening, and simulated dissolved air flotation.

Process

The following process-related conclusions were developed based on the bench-scale testing program:

1. The hydroxide and sulfide precipiation sequence, including the segregation and destruction of cyanide wastes, proved to be an effective method of treating a variety of wastes that contained cyanides and toxic heavy metals.

2. The presence of iron in the ferrous state when precipitating residual heavy metals with sulfide enhances the degree of removal of the metals.

3. Carboxylic ion exchange instead of the metal sulfide precipitation is also effective but not as attractive as the latter. The carboxylic ion exchange step was found even more effective downstream of the sequence of hydroxide and sulfide precipitation as a final polishing step. Metal sulfide precipitation in the presence of added ferrous iron is extremely convenient and effective when carried out in the same reaction vessel in the presence of hydroxide precipitates. For this reason, it is suggested that carboxylic ion exchange not be used in this treatment sequence.

4. The most difficult operation for handling cyanide wastes is the oxidation of complex nickel cyanides. A long exposure time requiring as much eight hours is needed with sodium hypochlorite dosage in order to completely oxidize cyanides. Neither the sulfide precipitation step nor the carboxylic ion exchange, nor a combination of the two, will remove nickel adequately if the complexes are adequately oxidized.

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5. The problem of receiving wastes that may contain ammonia, chrome in the hexavalent state, and cyanides requires that all metals wastes be treated to remove cyanides and reduce chromium whether or not it is believed they are present. This problem can easily be solved by segregating wastes containing large portions of cyanide from acid wastes.

6. In this study it was found that foam fractionation was not as effective for separating soluble nonmetallic toxic substances as was coagulation in the presence of a suitable polyelectrolyte followed by dual-media filtration and carbon adsorption. Foam fractionation is not attractive because (1) it may pollute the atmosphere; (2) the need for providing a liquid spray to collapse the float produces another liquid effluent that must be dealt with; and (3) it is not as effective as the coagulation filtration sequence.

7. The use of filtration (anthracite and sand) removed a higher proportion of particulate matter when used downstream of the coagulation processes. It was found that the use of activated carbon above the sand to replace the anthracite in the case of the proposed plant was not likely to be cost effective.

8. Generation of sulfide sludge and hydroxide sludge in the same reactor rather than separate vessels produced a sludge that easily settled and dewatered. The supernatant contained less residual soluble heavy metals than if the hydroxide sludges were removed first.

Plant Design Considerations

Based on the bench-scale studies conducted, the following design considerations were derived for a residual waste treatment facility:

1. Due to the relatively small volume of each type of industrial waste anticipated and the need for segregation of these wastes, tanks, equipment, and unit processes will be duplicated where possible and sized such that their combined capacities can handle design flows.

2. Due to the widely varying nature and complexity of the waste and the relatively small volume of wastes, batch processing will be used.

3. The requirement to interchange units to handle waste loadings, the need for uninterrupted operations during future expansions, and the desire to minimize costs of expansion require that piping and equipment arrangements provide maximum flexibility in the operation.

4. Optional reclamation processes (namely, ion exchange softening and reverse osmosis) have not been included in the design considerations. If reclamation of the final process water or if certain treatment difficulties arise on wastes considered in this study, then these options can be considered at a later time.

5. The residual waste treatment facility would require approximately one-half hectare of land.

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Cost

Based on process and design considerations, cost estimates were made for the construction, operation and maintenance of a residual waste treatment facility. These costs are as follows:

1. Capital cost	$1,472,000 (ENR = 2915)
2. Annual capital cost . . . . (7 percent interest, 20 years)	$139,000
3. Annual operation and maintenace	155,000
Total Annual Cost	$294,000

ORGANIC WASTE STUDY

The following organic wastes were evaluated relative to their individual impact on the solid waste disposal problem in Ventura County:

1. Municipal wastewater sludge
2. Animal manure
3. Vegetable and produce packing wastes
4. Meat and fish processing wastes

Problem solids were defined as solids which are not presently handled in a beneficial manner. Alternative treatment, handling, and/or disposal schemes were developed and evaluated for these problem solids.

The following conclusions were developed based on an in-depth survey assessing present and future (10 years) waste quantities and evaluation of current and proposed practices for treatment, handling, and/or disposal of wastes for each category:

1. Municipal wastewater sludges are the primary problem solids in Ventura County. The most cost-effective alternative to handle and dispose of these sludges is by centralized trucking to the Simi Valley Class I landfill site. This conclusion, however, is heavily dependent on the actual implementation of currently drafted State Health Department sludge disposal guidelines which will curtail the existing practices.

The estimated cost for the centralized trucking scheme is $22 per metric ton on a dry weight basis. This cost is based on leased trucking schedule at $35.00 per hour and hauling to the current Class I landfill site in Simi Valley which has a disposal cost of $2.75/metric ton.

2. Animal manures are currently being handled in a beneficial manner and present no significant problems. No project is needed to handle animal manure.

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3. Agricultural wastes are being handled in a near optimum fashion. Over 85 percent of the waste produced is utilized beneficially. The remaining 15 percent is disposed of in a cost-effective manner. No project is needed to handle agricultural wastes.

4. Meat and fish processing wastes are produced in an insignificant quantity and, therefore, the current practice of landfilling appears to be the most effective. No project is required.

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SECTION 3

RECOMMENDATION

RESIDUAL WASTE TREATMENT FACILITY

The recommendations which are presented are based on the conclusions derived from the bench-scale testing program and on the projection of the maximum frequency and quantity of wastes which can be anticipated to be delivered at the plant in any single working day.

Heavy Metals Wastes

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1. Storage and treatment are to be carried out in the two pairs of storage-reaction tanks. Each pair will consist of one 18.9 cubic meter capacity tank for cyanide and one 37.8 cubic meter capacity tank for non-cyanide heavy metal waste. Upon destruction of cyanides the wastes will be transferred to the non cyanide storage-reaction tank for further treatment.

2. The storage-reaction tanks should be equipped with appropriate safety features to prevent accidental intermixing of cyanide and non cyanide metallic wastes; i.e., alkaline cyanide metallic wastes would not become acidic before the destruction of cyanide.

3. The storage-reaction tanks would be equipped with appropriate piping, valves, equipment, and appurtenances to enable complete process control including settling, decantation and sludge transfer.

4. The decantates from non cyanide storage-reaction tanks are to be filtered by dual media filters and further treated/polished by carbon adsorption.

5. The product water would be used for backwash of the filters and carbon adsorbers.

Metallic Sludge Thickening and Dewatering

1. Sludge thickening is to be carried out in nine 18.9 cubic meter capacity storage and supernate decantation tank equipped with settling tubes.

2. The thickening tank is to be used for future dewatering studies if need arises.

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Nonmetallic Toxic Wastes

1. Storage and treatment would be carried out in two independent storage-reaction tanks. Each tank will be 22.7 cubic meter capacity and will be capable of storage, coagulation, flocculation and settling.

2. The storage-reaction tanks are to be equipped with appurtenances for fast mix of chemical additions and slow mix for coagulation-flocculation, for decantation and removal of sludge and for independent chemical feed.

3. The clarified effluent should be filtered by dual media filters and further treated by carbon adsorption.

Nonmetallic Sludge Thickening and Dewatering

1. The sludge thickening is to be carried out in one 1.9 cubic meter capacity storage and supernate decantation tank equipped with settling tubes.

2. Future dewatering of nonmetallic sludges can be alternately handled by a metallic sludge dewatering device if the need arises.

Oil Wastes

Oil Wastes Separable by Decantation--

1. Oil wastes separable by decantation should be handled by two independent 15.1 cubic meter capacity storage-decantation tanks.

2. The aqueous effluent would be treated in the same way as either nonmetallic toxic wastes or noncyanide heavy metal wastes, or both, depending on the constituents.

Emulsified Oily Wastes--

1. Emulsified oily wastes are to be handled by two independent 15.1 cubic meter capacity storage-demulsifier-decantation tanks.

2. The aqueous effluent from demulsified wastes will be handled as in the case of separable oily wastes.

3. Wastes which cannot be demulsified or which contain significant suspended soilds will be handled by a dissolved air flotation (DAF) device. Liquid effluent from the DAF device will be handled as in the case of separable oily wastes.

Oil Concentrate--

1. Oil concentrate generated by each of the treatment systems would be disposed of by reprocessing offsite.

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Brine Wastes

1. Brine wastes will be treated only if required.

2. Brine wastes would be treated in one or more of the other reaction tanks as required depending upon pollutants to be removed.

3. The chemical feed storage system associated with the heavy metal waste storage-reaction tanks is to be employed in the treatment of brine wastes.

4. Brine sludge characteristics will be determined after enough sludge has been accumulated to perform the required experimental tests.

Receiving-Storage Tanks

1. The receiving-storage tanks are to consist of four 37.8 cubic meter tanks.

2. Tank piping and valving should be arranged to enable any one tank to receive any waste load and to enable transfer of tank contents to any handling/treatment system.

General Considerations

Equipment and Materials of Construction--

1. All equipment and materials exposed to residual wastes are to be corrosion resistant to every type of anticipated residual waste to be handled.

2. All storage and storage-reaction tanks should be constructed of fiber glass reinforced plastic of the same quality gel coat, so that in the event of plant expansions the uses of existing tanks will be completely interchangeable.

3. Tank bottoms are to be conical or hopper shaped to permit ready removal of sediment without expensive scraper mechanism.

Laboratory and Personnel--

1. A modern laboratory facility with good analytical equipment should be available on-site for conducting immediate analyses.

2. An experienced chemist or chemical engineer must be available for the operation of the plant.

Source Control Program--

1. A comprehensive, well-coordinated source control program should be implemented. A key element of the program will be the prevention of mixing of nontreatable or complex compounds from the residual wastes to be treated.

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Facility Expansion--

The design of the plant is to be flexible to permit expansion readily without disruption of service and excessive modification costs.

ORGANIC WASTE MANAGEMENT SCHEME

The recommendations presented are based on the conclusions derived from the organic waste surveys and the evaluation of current and proposed practices for treatment, handling and/or disposal of organic wastes.

Municipal Wastewater Sludges

1. Implementation of a centralized trucking service to 13 wastewater treatment plants should be on a scheduled basis and staged to coincide with issuance of sludge disposal guidelines.

2. Upon issuance of sludge disposal guidelines, flexibility to react as necessary should be maintained.

Animal Manure

No project is recommended.

Vegetable and Produce Packing Wastes

No Project is recommended.

Meat and Fish Processing Wastes

No project is recommended.

SECTION 4

RESIDUAL LIQUID WASTE

PRELIMINARY PLANNING

As noted earlier, the preliminary planning work included the development of the research outline, identification of quantities and types of wastes which would be treated, a literature search, selection of the proposed treatment processes, and final preparation of a project budget. Where feasible, pilot-plant studies were conducted on wastes and processes identified in the preliminary planning state. The pilot-plant studies involved preparation of a testing program for production of design parameters fundamental to Phase II work.

Identification of Residual Wastes

As late as 1971, there was no compiled information about the types and quantities of industrial wastes generated in Ventura County. Major residual wastes in the region were initially identified in 1972 using a survey of existing activities in the county. The postcard survey form shown in Figure 2 was mailed to 417 companies within the county. Company names and addresses were compiled using information from the Chamber of Commerce, local Economic Development Association, and the yellow pages of the telephone directory. Fifty-one percent of the cards were returned. The high return rate is attributed to the briefness of the information requested and the tendency of many companies to report the generation of no wastes when this was not the case. Follow-up phone contact was made with 75 percent of the companies to check data received from certain select industries and to gather information from major industries that did not respond.

In subsequent follow-up surveys in 1974 and 1976, the specific quantities and types of wastes which require residual waste treatment had been identified. Due to the impracticality of segregating each waste encountered, the wastes were grouped into logical categories based on their treatability. Table 1 summarizes the results of the waste survey.

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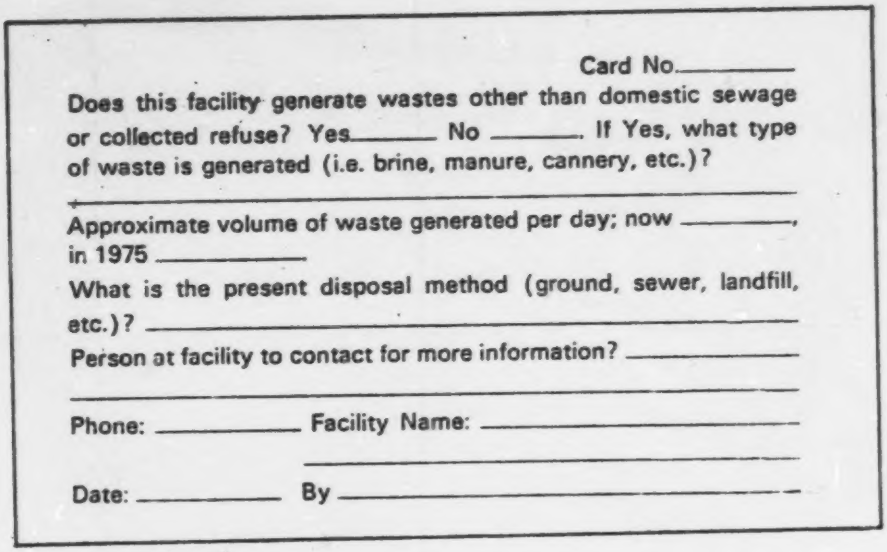

Card No.________

Does this facility generate wastes other than domestic sewage or collected refuse? Yes______ No ______. If Yes, what type of waste is generated (i.e. brine, manure, cannery, etc.)?

____

Approximate volume of waste generated per day; now ________, in 1975 ________

What is the present disposal method (ground, sewer, landfill, etc.)? ________________

Person at facility to contact for more information? ________

____

Phone: ________ Facility Name: ____________

____

Date: ________ By ________________

Figure 2. Postcard survey form (1971 Survey).

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TABLE 1. SUMMARY OF RESIDUAL LIQUID WASTE SURVEY

	Present Need Hard Value		Conservative Near-Term Projection	
	M^3/Day	M^3/Mth	M^3/Day	M^3/Mth
Toxic Metallic Wastes	0.9	20.8	† 16.8	370.6
Non-Metallic Toxic Wastes	2.8	62.4	§ 22.7	499.6
Brines*	11.4	249.8	15.1	333.1
Oil & Grease	1.9	41.6	2.1	45.8
TOTALS	17.0	374.6	56.7	1,249.1
Holding Capacity #	37.8 M^3		13.5 M^3	

*Includes only brine wastes which are currently trucked for disposal.

†Increase due to current pre-treatment operations stopping at industrial sources.

§Includes additional wastes (3.8 M^3/day) from Class I wastes.

#Based on the on-site holding capacities of industries that are considered users of this facility and the monthly dumping cycle anticipated.

A description and discussion of each waste category follows.

Toxic Metallic Wastes--

Wastes in this classification come primarily from metal plating, etching, and cleaning in metal finishing operations and are considered as toxic metallic wastes. Principal contaminants are copper, zinc, chromium, cadmium, nickel and tin. Iron is also a common constituent of metal treating wastes, but is non toxic. Cyandies, although not metallic, are normally used as complexing agents in metal-plating and are a common contaminant. Other toxic metals of concern are salts of lead, used in pottery glazes; mercury, used in herbicides and disinfectants; and various rare elements, used in paints and glazing pigments. Nitric, hydrofluoric, hydrochloric and sulfuric acids; sodium hydroxide, ammonia and trisodium phosphates are considered in the metallic waste class because of their common occurrence in metal cleaning, etching, and degreasing operations.

The control, treatment and disposal of these toxic metallic wastes is therefore of primary concern.

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Nonmetallic Toxic Wastes--

Wastes in this classification are a heterogeneous class of organic chemicals produced and utilized for their toxic properties. Examples are phenols, creosote, formaldehyde, and various chlorinated hydrocarbons used as insect and pest controls. Although small amounts might be received at full strength as tank drainage or condemmed stock, it is anticipated that any substantial quantities of these materials would be well diluted with fresh water, as from the flushings of containers or washing equipment. This class also includes water-carried mixtures of miscellaneous solvents which, although not necessarily toxic, usually can impart a persistent taste or ordor to the water being treated.

The problem with the normal nonmetallic toxic waste is to separate the usually small toxic or odorous fractions from the large quantities of fresh water in which they are normally received and then convert them to less hazardous, more manageable forms.

Brines--

Most brines come from petroleum production and citrus packing operations. Much of the brine from oil production has flotable and emulsified oils, and residual hydrocarbons, which are difficult to remove without special treatment. Miscellaneous oil field wastes include boiler blowdown, cooling tower blowdown, dehydrator washdown and container flushing.

Disposal to the groundwater is intolerable as the groundwaters in Ventura County have an adverse salt balance. Ocean disposal must be used, but only after hydrocarbon and sediment removal.

Oil and Grease (Oily Waste)--

Oil and grease, or oily wastes, coming to the facility would consist mostly of residual petroleum which is normally found in tank sump pumpings, oil field sludge, and oil saturated materials from accidental spills of petroleum production operations. Many residual oil wastes are now collected and reclaimed; however, significant quantities still find their way onto the land. Other sources of oily wastes are equipment washings, machining operations and gas stations.

Some oily wastes contain toxic compounds, while some oils are very slowly degraded and can persist in the environment for years. Unless proper treatment and disposal practices are used, ground and surface water pollution will result.

Development of Preliminary Treatment Concepts

Preliminary treatment concepts were developed for each waste category using reference material available from Ventura Regional County Sanitation District, EPA, other public agencies, and technical libraries.

A description of treatment processes for each category of residual wastes is given following their conceptual development. Processes that are novel to the particular applications proposed are recommended for preliminary evaluations including bench-scale testing. For purposes of simplifying dis-

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cussions, a separate series of treatment processes is shown in the early sections for each major category of waste being treated. In the final section, a number of processes are combined to eliminate unnecessary redundancy and improve the economic feasibility of treatment.

Toxic Metallic Waste Treatment--

Due to the variations in the types of heavy metal wastes, treatment should be separated in accordance with waste type. Segregated heavy metal waste collection, transport and treatment is recommended. Separate treatment of the subcategory wastes (namely, cyanide wastes, ammonia wastes, and chromate wastes) are discussed in the following subsections.

In each heavy metal treatment scheme, major reliance is placed on formation, removal and partial dewatering of metal precipitates. The technology of such treatment is well established.

Cyanide wastes--Hydrocyanic acid (HCN) is a potent poison, an exceedingly weak acid, and an exceedingly strong complexing agent. The acid is so weak that solutions of cyanides at pH less than 8.5 are dangerous because of the volatility of HCN. The complexes that cyanide ions form with heavy metals are so strong that some of the heavy metals do not precipitate from cyanide solutions at very high pH. However, cyanide ion and cyanide heavy metal complexes in solution are strong reducing agents, and this property is the basis for their destruction.

Cyanide destruction is carried out either continuously or in a programmed batch operation. The cyanide-bearing waste is first oxidized with chlorine, sodium hypochlorite or hydrogen peroxide at a pH of about 9.5, using sodium hydroxide to maintain the pH. The reactions are:

$$CN^- + 2OH^- + Cl_2 \longrightarrow CNO^- + 2Cl^- + H_2O$$

or

$$CN^- + OCl^- \longrightarrow CNO^- + Cl^-$$

or

$$CN^- + H_2O_2 \longrightarrow CNO^- + H_2O$$

The cyanate ion (CNO^-) formed is less than 1/1000 as toxic as cyanide ion, and cyanates are not generally listed as wastes to be controlled in discharge regulations. However, it is possible for the cyanate ion to be reduced back to cyanide in anaerobic surroundings; and for this reason, the cyanate is usually further oxidized at a pH of about 8.5 to free nitrogen and carbon dioxide. The pH is maintained by adding H_2SO_4 and NaOH solution as required. Chlorine or sodium hypochlorite is used in the oxidation. The reactions are:

$$2CNO^- + 3Cl_2 + 6OH^- \longrightarrow 2HCO_3^- + N_2 + 6Cl^- + 2H_2O$$

or

$$2CN)^- + 3OCl^- + H_2) \longrightarrow 2HCO_3- \times 3Cl^- + N_2$$

Detention times for the oxidation reactions are approximately 15 and 25 minutes for the first and second stages, respectively. Oxidizing agent

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feed is activated by an oxidation-reduction potential probe, and acid or base feeds are activated by a pH probe. A schematic diagram of this subsequent cyanide waste treatment processes is given in Figure 3.

Heavy metal precipitation--The metal ions which have been decomplexed as a result of the cyanide oxidation will begin to precipitate as hydroxides which are reasonably insoluble at the high pH maintained in the oxidizing medium. It is common practice to carry out the two stages of oxidation continuously in a two-compartment vessel and to filter effluent from the second compartment for discharge or beneficial reuse. However, there are problems associated with collecting a suitable sludge in such an apparatus:

1. The sludge is formed primarily in the first reaction vessel and is therefore wetting by cyanate solution and should not be blown down for dewatering without returning the liquid phase from the sludge dewatering and cake rinsing operations to the feed.

2. Any floc escaping from the first reaction vessel may collect nitrogen bubbles that are generated in the second oxidation vessel and float.

There is still another fundamental problem with the process for destroying cyanides, cyanates, and simultaneously precipitating the heavy metals as the hydroxides. The equilibrium solubilities of some of the hydroxides are too high to meet discharge requirements--as an example, cadmium hydroxide $Cd(OH)_2$, which is soluble to the extent of about 0.1 to 1.0 mg/l whereas some statutes allow only 0.01 mg/l (all mg/l as Cd++). A residual turbidity of 0.1 JTU or more from the second vessel may also produce an effluent that exceeds recommended standards during the period immediately following the regeneration and backwashing cycle of the effluent filter.

Sulfide precipitation of the effluent from the cyanide destruction and hydroxide precipitation overcomes the problem of partial hydroxide solubility. The concentrations in moles/liter of some heavy metals in equilibrium with their sulfides are shown in Table 2.

All of these concentration values are exceedingly small. Effective treatment, however, will not be achieved by simply treating a saturated hydroxide solution of the heavy metals with a soluble sulfide; the flow would be so small and so dilute that it would not settle in a reasonable time, nor could it be completely filtered out. Hydrogen sulfide is a potent poison but one with such a disagreeable odor that its presence is nearly always detected in time to avoid lethal human intakes. Hydrogen sulfide is also a weak acid; so weak that the odor of H_2S can be detected even above a moist highly alkaline sulfide salt or a sulfide solution of high pH. Thus soluble sulfides or H_2S cannot be used as precipitants with impunity, except in closed systems which are never opened to the atmosphere when an appreciable concentration of excessive soluble sulfide is present in the solution. There are, however, two ways to circumvent the problem of H_2S volatility. These result from the following facts: (a) the solubility of FeS is exceedingly low but many orders of magnitude higher than the other heavy metal sulfides listed above, so that, (b) the sulfide ion concentration is a solution saturated with FeS, and in the presence of FeS solid phase, can precipitate the

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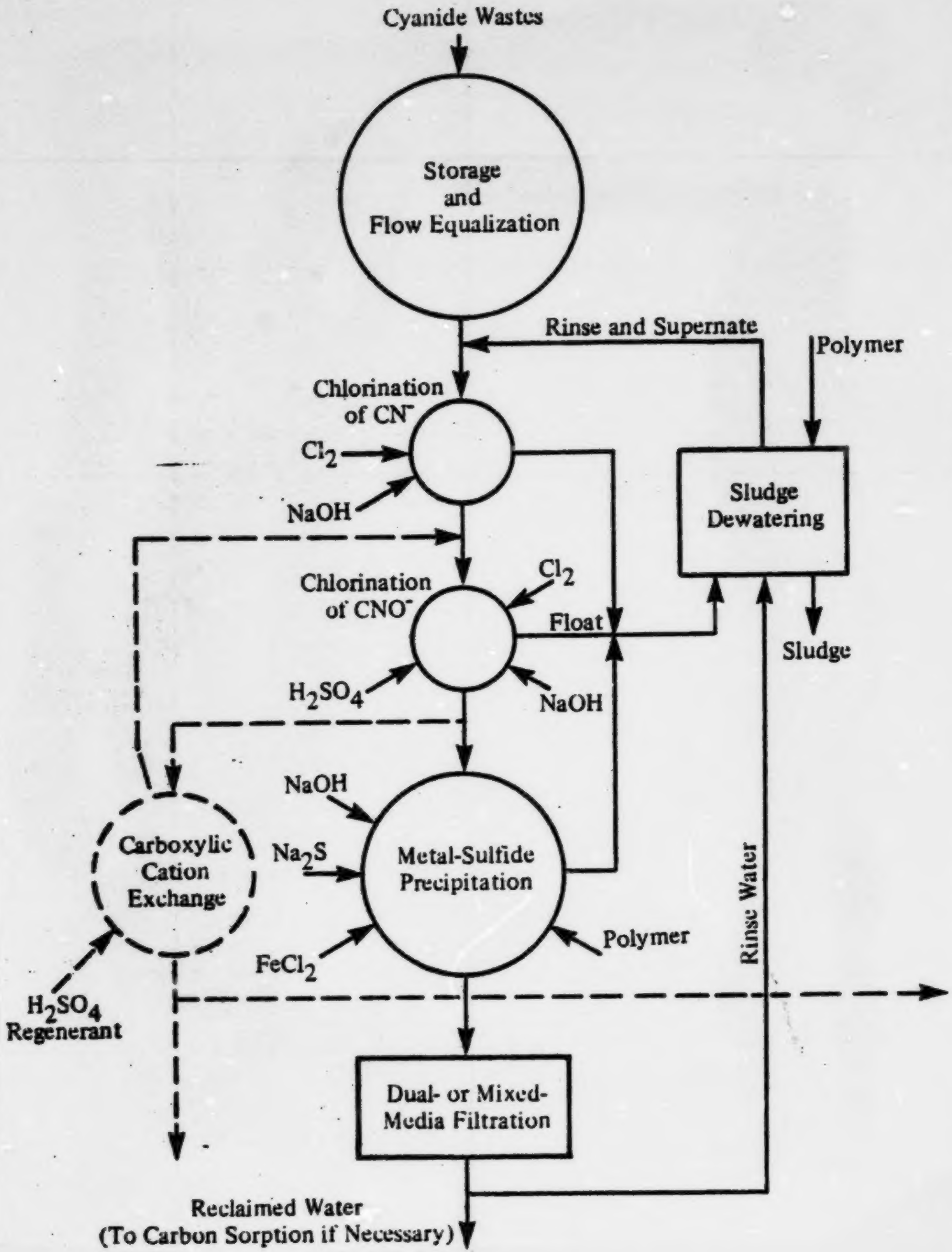
Cyanide Wastes
Storage and Flow Equalization
Rinse and Supernate
Polymer
Chlorination of CN⁻
Cl₂
NaOH
Sludge Dewatering
Chlorination of CNO⁻
Cl₂
Float
Sludge
H₂SO₄
NaOH
NaOH
Carboxylic Cation Exchange
Na₂S
Metal-Sulfide Precipitation
Rinse Water
Polymer
FeCl₂
H₂SO₄ Regenerant
Dual- or Mixed-Media Filtration
Reclaimed Water (To Carbon Sorption if Necessary)

Figure 3. Cyanide waste treatment schematic.

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TABLE 2. HEAVY METAL - SULFIDE SOLUBILITIES

Constituents	Solubility (moles/liter)
Mn^{++}	3.75×10^{-8}
FE^{++}	6.1×10^{-10}
Zn^{++}	3.5×10^{-12}
Sn^{++}	3.1×10^{-13}
Co^{++}	1.7×10^{-13}
Pb^{++}	1.8×10^{-14}
Cd^{++}	6.0×10^{-15}
Ag^{++}	3.4×10^{-17}
Bi^{++}	4.8×10^{-21}
Cu^{++}	9.2×10^{-23}
Hg^{++}	4.5×10^{-25}

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objectionable heavy metal sulfides down to or below their equilibrium values. As a result, FeS is a perfectly applicable precipitating agent, either used as a solid phase in a packed column through which the solution of heavy metal hydroxides is passed, or used as a precipitating agent formed in situ in a closed system. In the case involving in situ precipitation of FeS, a coagulant such as alum and/or a polyelectrolyte is employed and considerable detention time must be allowed in the flocculation zone of the vessel in which the precipitation is carried out. The pH of the solution must also be controlled. Figure 3 presents the schematic diagram of the treatment process described.

Ion exchange alternate for heavy metals--If the cyanides have been destroyed and the bulk of the heavy metals have been precipitated as the hydroxides, the heavy metals remaining in solution because of hydroxide solubility should be removed effectively and efficiently by cation exchange resins. The solution of the settled effluent from the cyanide destruction unit is alkaline and contains bicarbonate alkalinity because of the reaction of cyanate to form CO_2 and N_2. It would thus be amenable to treatment with a weakly acidic cationic exchanger (carboxylic functionality) in the hydrogen form. It can be expected that the capacity of this type of resin would be very high in this service and that the regenerant wastes could be recycled to the treating system that produces the settled effluent. The details for designing such an ion exchange system are well known and would not require further research.

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The ion exchange process could be integrated into the cyanide and heavy metal removal sequence of processes as an alternate to the sulfide precipitation process and is shown as a parallel process in Figure 3 and in subsequent heavy metal removal processes.

It is anticipated that the ion exchange and sulfide precipitation processes would be competitive. Sulfide precipitation has not been extensively utilized for reasons discussed above; however, if the procedures discussed are properly applied, the process would probably achieve the most complete and reliable removal of the heavy metals. Although ion exchange removals have been demonstrated and the process is also considered reliable, the sulfide process was selected. It was concluded that bench scale testing of the sulfide precipitation process would be useful prior to final design to assess the size of precipitate particles formed and the settleability/filtrability of those particles. Tube settlers might advantageously be employed in the sulfide precipitation.

Chromate waste--The term "chromate" is used here to indicate any kind of chromium compound in which the chromium is hexavalent. Whether the term chromate or dichromate is used would, of course, more correctly depend on the free acidity of the solution since chromate-dichromate equilibria depend on the hydrogen ion concentration:

$$2CrO_4^{=} + 2H^{+} \rightleftarrows H_2O + Cr_2O_7^{=}.$$

Chromates are highly toxic substances and their discharge to the aquatic environment is strictly controlled by regulatory agencies.

1. Chromate destruction

Precipitation of chromate ion as the barium salt ($K_{sp}BaCrO_4 = 8.5 \times 10^{-11}$) is feasible, but reduction of the chromate ion to chromic ion (Cr^{+++}) and precipitation of chromic hydroxide, along with other heavy metals in the solution, is more practical ($K_{sp}Cr\ (OH)_3 = 6.7 \times 10^{-31}$).

The reduction is carried out in the first compartment of a two-compartment vessel at pH 2.5-4.0 using sulfur dioxide or sodium metabisulfite dissolved in water as the reductant. The stoichiometry of the reduction may be represented by:

$$2Cr^{6+} + 3SO_2 \longrightarrow 2Cr^{+++} + 3SO_4^{=}$$

or

$$2Cr^{6+} + 3HSO_3^{-} \longrightarrow 2Cr^{+++} + 3HSO_4^{-}$$

For the purposes of BSTP, sodium metabisulfite was used as the reductant.

Acid feed is controlled by a pH probe; and an oxidation-reduction potential probe controls the dosage of reducing agent. Figure 4 presents the schematic diagram of the chromate destruction and subsequent chrome waste treatment.

2. Chrome precipitation

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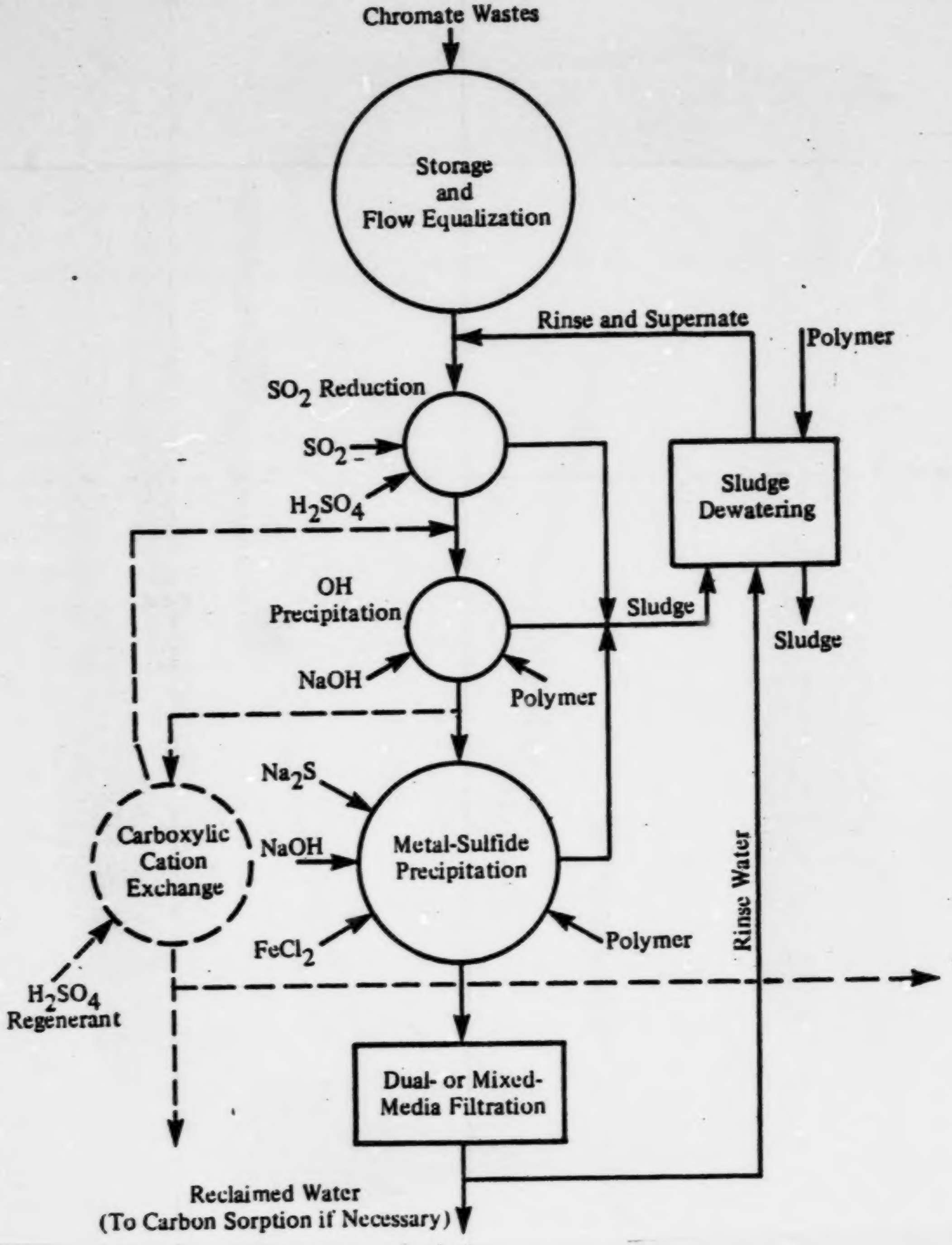
Chromate Wastes
Storage and Flow Equalization
Rinse and Supernate
Polymer
SO_2 Reduction
SO_2
H_2SO_4
Sludge Dewatering
OH Precipitation
Sludge
Sludge
NaOH
Polymer
Na_2S
Carboxylic Cation Exchange
NaOH
Metal-Sulfide Precipitation
Rinse Water
$FeCl_2$
Polymer
H_2SO_4 Regenerant
Dual- or Mixed-Media Filtration
Reclaimed Water (To Carbon Sorption if Necessary)

Figure 4. Chromate waste treatment schematic.

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The trivalent chromium and the ions of the other heavy metals in the previously reduced solution are then precipitated as hydroxides in the second compartment of the two-compartment vessel, at a pH of 8.5-9.0 which is established and maintained by the addition of sodium hydroxide solution through a feed line that is activated by a pH probe. A mild oxidant (e.g., for ferrous iron) may also be required.

Depending on the other heavy metals present and the presence of complexing agents (other than cyanide ion), it may be necessary to treat the effluent from the second compartment either by sulfide precipitation or by ion exchange polishing, as already discussed for wastes that originally contained cyanides. After filtration the effluent may either be wasted or reused.

Treatment of chromate wastes is somewhat analogous to that of cyanide wastes in that an initial chemical conversion is necessary, and residual heavy metals are removed by hydroxide precipitation followed by polishing with either sulfide precipitation or ion exchange. Combinations of processes subsequent to primary chemical treatment of these two wastes, therefore, is technically feasible and economically attractive.

Ammonia wastes--The addition of ammonia-containing compounds in etching processes creates a need to treat some heavy metal solutions for removal of ammonia to improve the efficiency of subsequent treatment. The presence of certain heavy metals. The zinc complex $Zn(NH_3)_4^{++}$, for example, may hold as much as 3 mg/l of zinc in solution at pH 8.[4] Precipitation with hydrogen sulfide (and other sulfides) would appear to be effective in the removal of all heavy metals in the presence of ammonia or other complexing agents for heavy metals; but if the etchant solution contains a strong oxidizing agent, such as $(NH_4)_2S_2O_8$, some of the sulfide will react with the oxidizing agent to produce free sulfur. Furthermore, after precipitation and reduction, the ammonia still remains in solution and would perhaps need to be removed by aeration, depending on the use of the effluent water. The ammonia could also be removed, or more correctly converted, by chlorination.

To provide for removal of ammonia, the recommended design, involving processes shown in Figure 5, would include at least partial ammonia stripping by air sparging at high pH. The subsequent oxidation by Cl_2 or NaOCl would serve as backup treatment. Following this degree of pretreatment, the heavy metal wastes would be subjected to the hydroxide precipitation process and to the same subsequent processes discussed above for other heavy metal wastes.

Organic contaminants in heavy metal wastes--The metal treating industry employs a long list of proprietary organic substances as chelating agents, brighteners, wetting agents, cleaning agents, degreasers and so forth. Some type of organic removal process, such as activated carbon adsorption, would therefore be useful somewhere in the purification scheme. However, depending on the organic waste load, the use of activated carbon could be quite expensive. Nevertheless an activated carbon treatment process should be available for removal of these substances with a bypass line provided for wastes without them.

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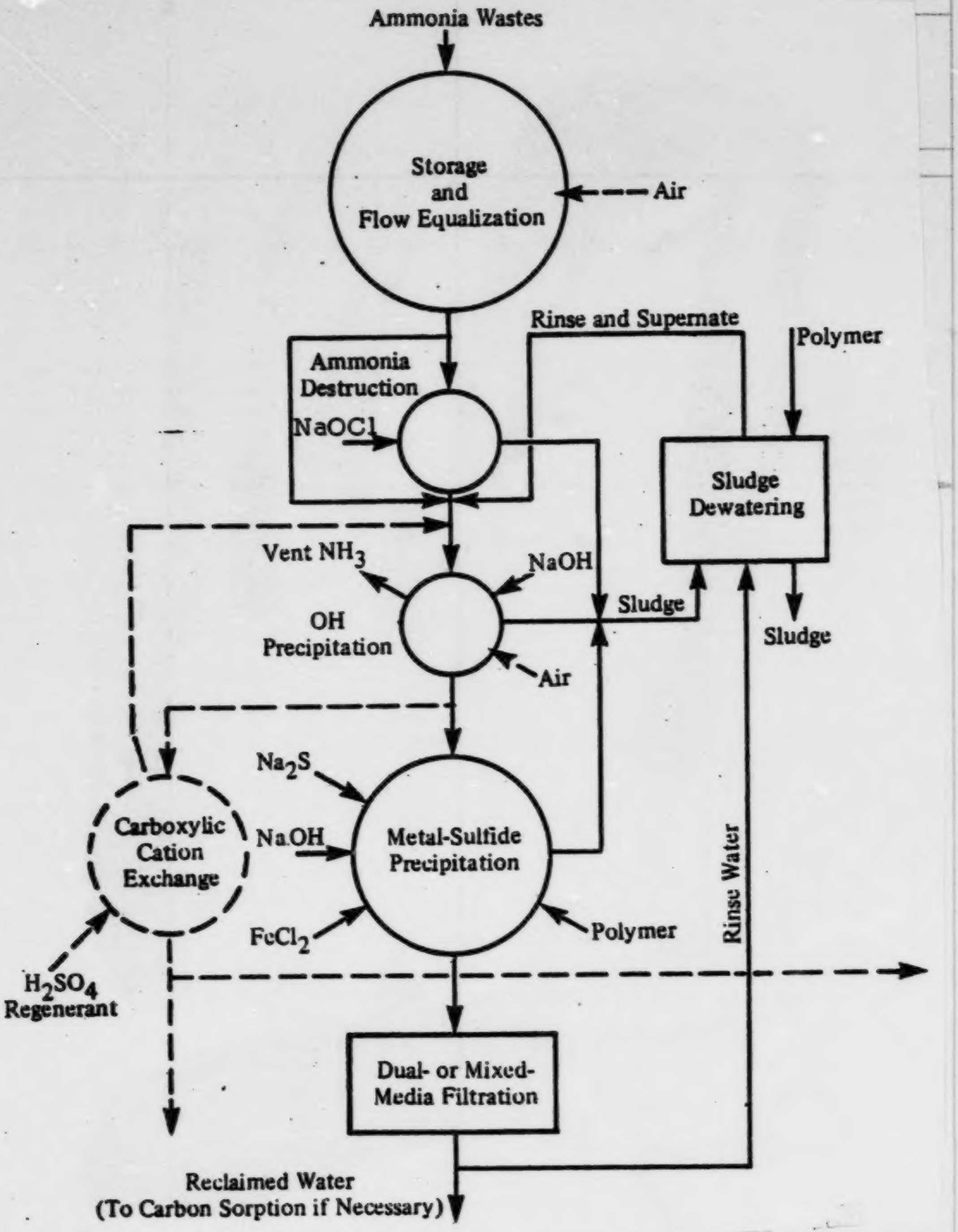
Ammonia Wastes
Storage and Flow Equalization
Air
Rinse and Supernate
Polymer
Ammonia Destruction
NaOCl
Sludge Dewatering
Vent NH_3
NaOH
Sludge
Sludge
OH Precipitation
Air
Na_2S
Carboxylic Cation Exchange
NaOH
Metal-Sulfide Precipitation
$FeCl_2$
Polymer
Rinse Water
H_2SO_4 Regenerant
Dual- or Mixed-Media Filtration
Reclaimed Water (To Carbon Sorption if Necessary)

Figure 5. Ammonia waste treatment schematic.

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Sludge dewatering--All hydroxide and sulfide sludges collected during treatment of toxic metal wastes are relatively dilute. A typical sludge blowdown will contain suspended solids concentrations as low as one percent. Disposal of such sludges without additional treatment would necessitate transport to a Class I disposal site.

Because of the adverse economics and high energy consumption involved in hauling dilute slurries, some degree of sludge dewatering may be needed. Among the methods available are gravity thickening, gravity dewatering, centrifugation, vacuum filtration and filter pressing. Selection of the proper sludge dewatering process can be guided by the nature of the sludges to be thickened. Hydroxide sludges exhibit a membrane-forming propensity during filtration. The membrane thus formed slows the passage of water. A successful sludge dewatering device, therefore, would be one in which initial lining of the membrane would not play a dominant role. Continuous exposure of cleaned membrane would be preferred. Filter presses which do not expose renewed surface on a continuous basis would probably require excessive pressures at an early stage of filtration. A gravity dewatering device with a first stage and compression rollers in a second stage, if required, would probably be the most successful device. A number of such dewatering devices are commercially available and should be carefully evaluated at the time of final preparation of design plans and specifications.

Brine Waste Treatment--

The objective of treating brine wastes is to remove contaminants such as oil in order to obtain an effluent that can be safely charged into the ocean environment. Information on the quality of brine wastes to be received at the plant site indicates that these wastes have already been passed through API separators before being sent to the waste treatment facility. It is therefore believed that an API separator is not needed for treatment of brine wastes prior to flotation facilities. It is likely that the sediment drained from the bottom of the flotation unit would be much too dilute to economically haul or pump to a landfill site. It is also believed that the skimmings will not break up readily in the gravity sedimentation separator. A float which contains oil, sediment, polyelectrolytes, and air is usually quite stable and difficult to break up.

Because of these factors, the brine wastes could probably be treated more successfully by foam fractionation-flotation as opposed to straight dissolved air flotation. Foam fractionation is a relatively new technique, but it has proved to be an inexpensive method for clarifying desalting plant blowdown brines from seawater distillation units and for partial removal of some heavy metals from the brine. It has also been demonstrated to be effective in removing colloids and other particulates from agricultural drainage waters. It can, with appropriate polyelectrolyte aids, remove organic matter including substantial quantities of oils.

Foam Fractionation-flotation--The foam fractionation-flotation process is relatively simple. It employs countercurrent flow of solution containing foaming agents and air sparged in at the bottom of a column. A schematic diagram of the process is given in Figure 6. The brine feed is introduced near the top of the fractionation column and below the foam layer. It flows

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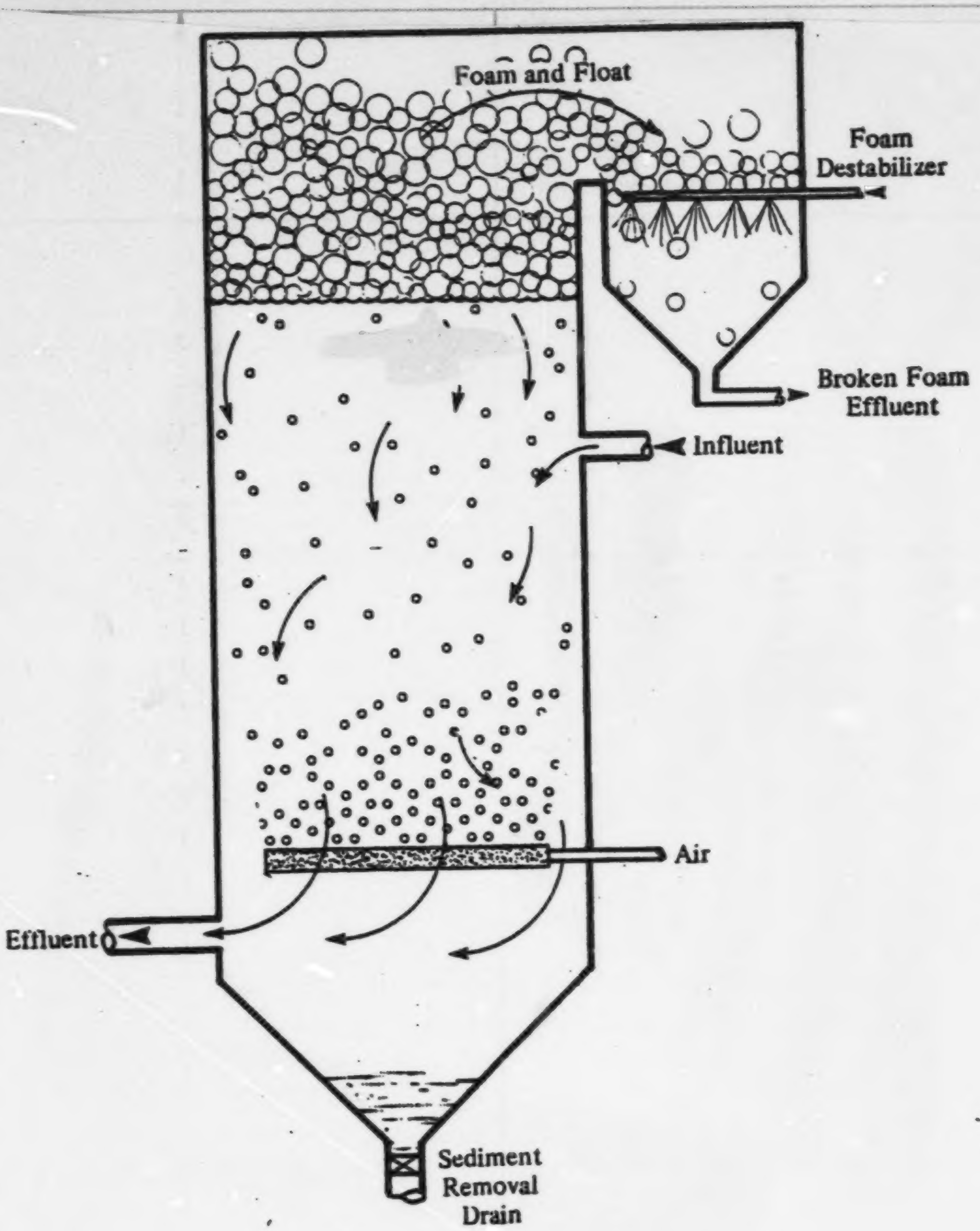
Foam and Float
Foam Destabilizer
Broken Foam Effluent
Influent
Air
Effluent
Sediment Removal Drain

Figure 6. Foam fractionation-flotation process schematic.

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countercurrently downward against a rising stream of small bubbles dispersed throughout the solution by a small bubble air diffuser, common to those used in aeration basins of activated sludge wastewater treatment plants. The foam is removed through a covered weir located at the top of the fractionation column. It is broken up by spraying collapsed foam water in the foam. The clarified effluent comprises approximately 95 percent of the feed and its essentially high quality water. For further purification, filtration or sedimentation can be provided as subsequent treatment. If small traces of organic constituents are still present and unacceptable, the effluent could also be treated by activated carbon sorption. The proposed flow scheme for brine wastes is shown in Figure 7.

The foam fractionation device frequently includes a hopper-shaped bottom for collecting nonflotables that settle out in the column below the air diffusion device. For wastes in Ventura County, it is anticipated that such sediment would be relatively small in quantity; however, provisions for its removal are included in the process recommended.

It is well known to purveyors of polyelectrolytes and sludge dewatering equipment that oil wastes are dewatered more completely and efficiently in the presence of certain particulate matter. Secondary sewage treatment plant sludge, masserated newspapers in small proportions, or just plain dirt are often useful dewatering aids for oily wastes. For such wastes at the proposed treatment plant, the float solids should be dewatered in the same type of equipment used for dewatering hydroxide and sulfide sludges. It may turn out that all of the sludges should be dewatered simultaneously in the same equipment.

The foam fractionation-flotation device can be operated over a range of flowrate, chemical feed and air supply quantities. Its successfull operation in similar wastes implies that it will be a very successful process for the proposed application, and it is recommended that pilot-plant testing be conducted to confirm its particular application at this installation. Included in the pilot-plant testing should be an assessment of the float characteristics relative to its ease in dewatering.

Nonmetallic Toxic Waste Treatment--

The initial treatment concept for nonmetallic toxic wastes involved air flotation, carbon sorption, and reverse osmosis. A common unit process for treatment of the float was shared with the initial brine waste treatment concept. Water separated from the float was recycled to the air flotation unit. Subsequent analysis indicated that the nonmetallic toxic wastes contained a considerably lower mineral content than the brine wastes. It would seem advantageous to keep them separated from the brine wastes and consider additional treatment that may enable reuse.

To minimize the amount of regeneration or replacement of activated carbon, it is important to remove as much of the organic load as possible before the nonmetallic wastewater is treated by carbon sorption. It is proposed, therefore, that the same kind of foam fractionation-flotation device discussed above be used to treat the nonmetallic toxic wastes as well as the brine wastes. This could be done by providing a parallel treatment unit or

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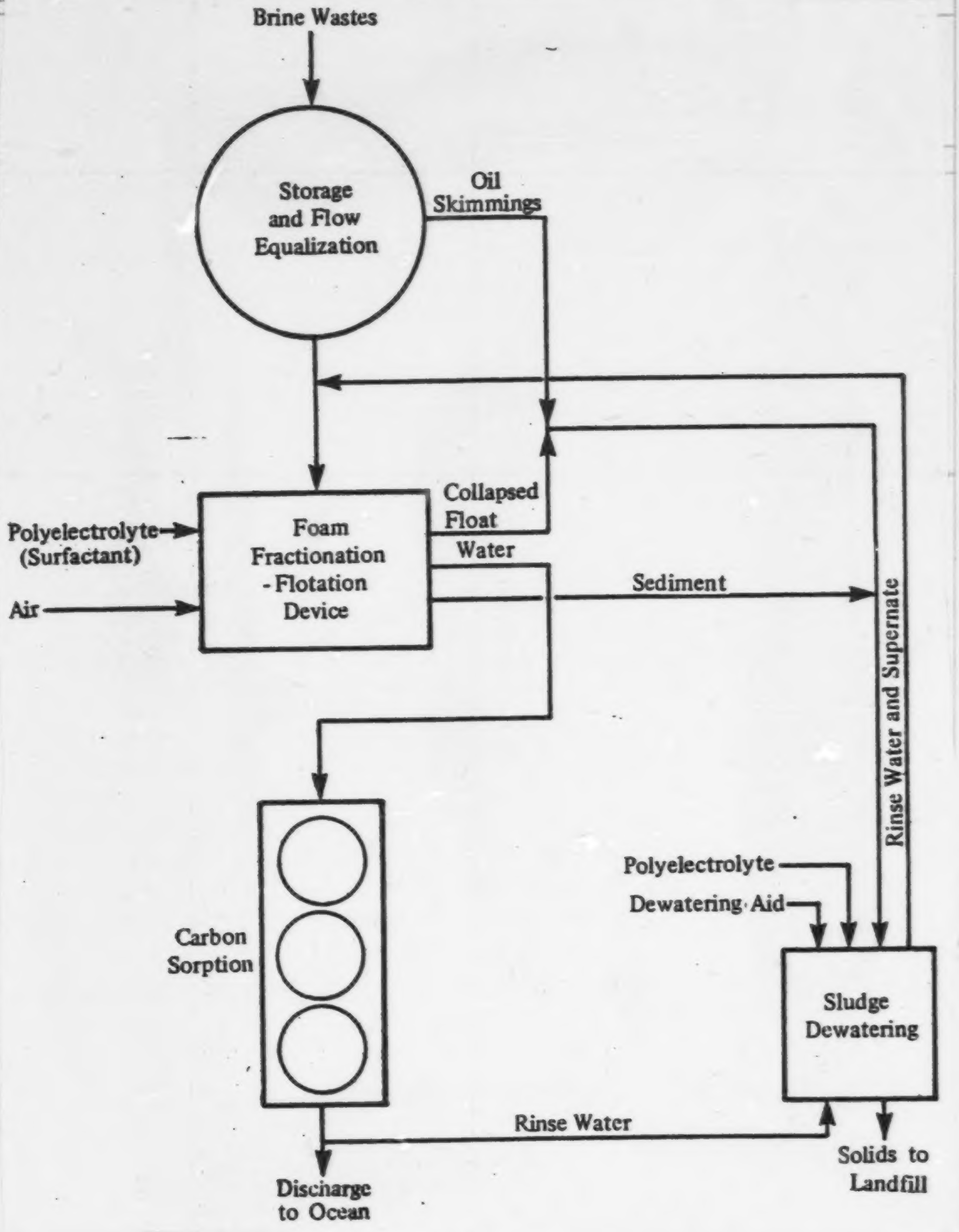
Brine Wastes
Storage and Flow Equalization
Oil Skimmings
Collapsed Float
Polyelectrolyte (Surfactant)
Foam Fractionation - Flotation Device
Air
Water
Sediment
Rinse Water and Supernate
Polyelectrolyte
Dewatering Aid
Carbon Sorption
Sludge Dewatering
Rinse Water
Discharge to Ocean
Solids to Landfill

Figure 7. Brine waste treatment schematic.

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by alternating the use of a single unit. The effluent from this treatment device would be treated with activated carbon.

The effluent from the carbon would probably contain a considerable amount of calcium hardness. Although demineralization would not be needed at this site for disposal, it may be required for certain types of reuse. If reverse osmosis were used, its influent should first be softened with an ion exchange softner. Reverse osmosis could also be used to produce a solution of high sodium concentration to be used subsequently for regeneration of an ion exchange medium. Without softening, reverse osmosis rejects about 90 percent of the sodium and nearly 99 percent of the calcium ions, which in the presence of alkalinity would cause precipitation of insoluble species. As a result, without softening it is probable that the regenerating stream sent to the ion exchange bed would contain approximately equivalent amounts of sodium and calcium. Calcium would be favored in the regenerant exchange equilibrium and prevent the bed from being properly regenerated with sodium.

In summary, the proposed treatment sequence for nonmetallic toxic wastes consists of storage, foam fractionation, and carbon sorption. A schematic diagram of the recommended processes is given in Figure 8.

Oily Waste Treatment--

The oily wastes management units in the proposed facility shall consists of storage and processing by way of an API separator with effluent sent to the foam fractionation-flotation device of the nonmetallic toxic waste treatment system. Flotables from the API separator would essentially consist of reclaimed oil. This sequence of treatment appears to be feasible and would produce a satisfactory product. Pilot-plant testing should, however, be done with this waste to determine the efficiency of its treatment by foam fractionation-flotation.

Preliminary Comprehensive Process Schematic--

The process units identified in the previous discussion for treatment of the different types of residual wastes are, in some cases, identical from one treatment scheme to another. It is not necessary to provide for an inordinate amount of duplication of process equipment units needed at a central plant. Some pieces of equipment may be employed simultaneously or alternatively to process several categories of wastes at appropriate stages in the treatment process sequence. The final composite flow sheet is presented in Figure 9. As will be discussed in the subsequent sections, a considerable degree of process combination is considered to be feasible for the final stages of treatment.

Preliminary Storage and Treatment Concept for Toxic Metal Wastes Not Containing Cyanide--

The preliminary concept for treating toxic heavy metal wastes, except those containing cyanides, begins with storage of collected wastes in a 227.1 cubic meter storage/equilization/reaction tank. Any wastes that contain ammonia, chromium, and/or toxic heavy metals may be stored in this tank for preliminary treatment and flow equalization. These wastes may be either basic or acidic as received.

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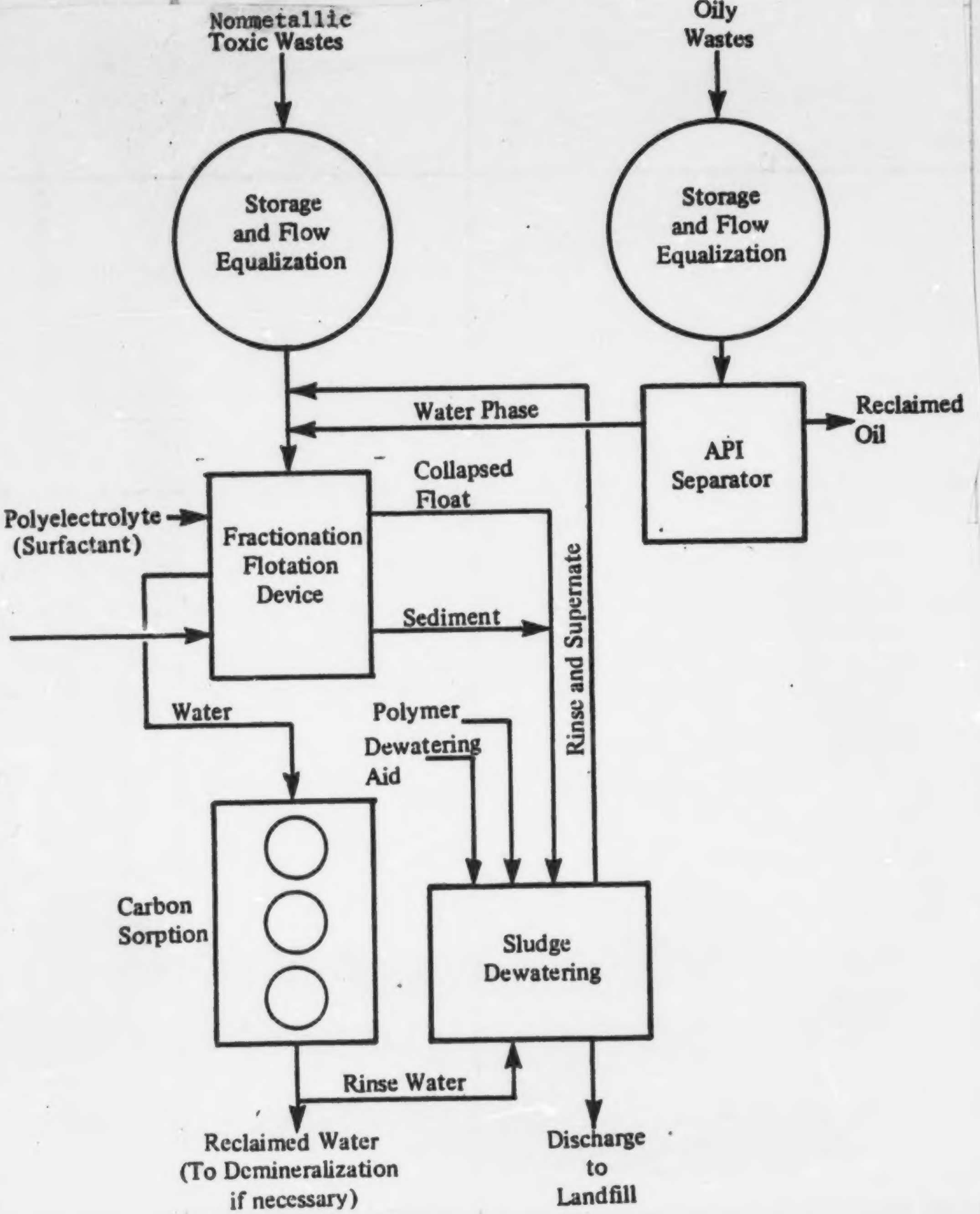
Nonmetallic Toxic Wastes
Oily Wastes
Storage and Flow Equalization
Storage and Flow Equalization
Water Phase
API Separator
Reclaimed Oil
Collapsed Float
Polyelectrolyte (Surfactant)
Fractionation Flotation Device
Sediment
Rinse and Supernate
Water
Polymer
Dewatering Aid
Carbon Sorption
Sludge Dewatering
Rinse Water
Reclaimed Water (To Demineralization if necessary)
Discharge to Landfill

Figure 8. Nonmetallic toxic and oily waste treatment.

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The tank would be equipped to introduce diffused air and is provided with a vent for allowing the ammonia, either free initially or generated from ammonium salts, to escape to the atmosphere. It is presumed that a full tank of these wastes will be collected over a period of from one to several days. This tank should also be equipped for:

1. The introduction of lime slurry (or sodium hydroxide solution) as called for by a pH probe set to establish and maintain an appropriately high pH.

2. The introduction of sodium hypochlorite (or chlorine) as called for by an oxidation-reduction potential probe set to maintain an appropriate oxidation-reduction potential.

3. The introduction of sulfuric acid (or other strong acid) solution as called for by the pH probe set to establish and maintain appropriately low hydrogen ion concentrations in two programmed steps.

4. The introduction of sodium sulfite solution or SO_2 gas to provide an appropriate reduction potential when required as called for by the oxidation-reduction potential probe.

This system would be designed to carry out the following chemical reactions in the tank by way of a programmed series of steps:

a. The removal of free and combined ammonia by maintaining a high pH and sparging with diffused air.

b. The oxidation of traces of ammonia and the oxidation of certain organic materials by breakpoint chlorination.

c. The reduction of hexavalent chromium by sulfide ion, the reoxidation of ferrous iron to the ferric iron state and the oxidation of excess sulfur dioxide by chlorination.

The treated liquid effluent from this storage and reaction tank is now appropriate to be processed by precipitation of the heavy metals.

A minor modification of the above storage and in-tank treatment processes would be one in which the large equalization basin is used solely for equalization and ammonia stripping, and a subsequent smaller process tank is added downstream to achieve the reduction of chromium and stabilization of other compounds. Such a smaller tank would be easier to control by pH and oxidation-reduction probe feedback-loop controls. The final decision regarding this modification versus the tow tanks discussed above should be made at the time of process design when more data on waste loads and scheduling are available.

From this point in the process, all heavy metal wastes would receive common sodium hydroxide precipitation treatment. The process unit would consist of a reaction-clarifier basin, with sludge being removed to a common central sludge storage dewatering system. Effluent from the precipitator

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would be treated by sulfide precipiation or, as an alternative, a carboxylic-acid cation-exchange unit.

Subsequent processes, namely, the sulfide precipitation, dual-media or mixed-media filtration, and carbon adsorption could remain unchanged regardless of which means is selected for hydroxide precipitation.

Preliminary Storage and Treatment Concept for Cyanide Wastes--

Toxic metal cyanide wastes must be collected and stored separately at the treatment plant site. Although the exact volume of these wastes is not known, a storage reservoir of approximately 37.8 cubic meters should be sufficient. The cyanide wastes must be basic as received and a pH probe must monitor the inlet closure of the inlet valve if an attempt is made to introduce acidic wastes. Similar to the storage tank provided for the other heavy metal wastes, this tank could also be equipped with chemical feeding and mixing apparatus to permit its use as a batch programmed reaction tank. The following provisions are recommended:

1. Equip the tank for introduction of a sodium hydroxide solution fed to maintain a high pH during two oxidation stages (the first to convert cyanide to cyanate and the second to convert cyanate to N_2 and CO_2).

2. Equip it for introduction of a sodium hypochlorite solution or chlorine to carry out the oxidation and an oxidation-reduction potential probe to monitor and control the introduction of the oxidizing agent.

Following oxidation of the cyanides, the wastes could be gradually transferred into the large waste storage tank used to equalize flows of the other heavy metal wastes.

Other Process Combinations--

Separate storage should be provided for nonmetallic toxic wastes, oily wastes and brine wastes. These wastes, however, could be treated with similar processes downstream of initial treatment. A separate API separator is used to remove the bulk of oil from the oily wastes. Following this removal, its effluent could be treated by the foam fractionation process initially designed to treat nonmetallic toxic wastes. In an analogous fashion, the brine wastes could be treated with the same foam fractionation unit provided that sulfur dioxide (to reduce any chromium that may be present from cooling tower blowdown) is fed into the line between the brine storage tank and the foam fractionation unit. In order to use the foam fractionation unit for all three of these different types of wastes, it would be necessary to schedule them in such a manner that the brine wastes would be treated separately from the other wastes which have some reclamation potential. The flow scheme in Figure 9 assumes that such programmed scheduling is feasible.

Effluent from the foam fractionation-flotation process could be reclaimed, if its mineral content is acceptable, by further treating it with dual- or mixed-media filters and/or activated carbon sorption. For demonstration purposes it is recommended that filtration and sorption be performed in separate units. In final prototype design, however, it may be possible to

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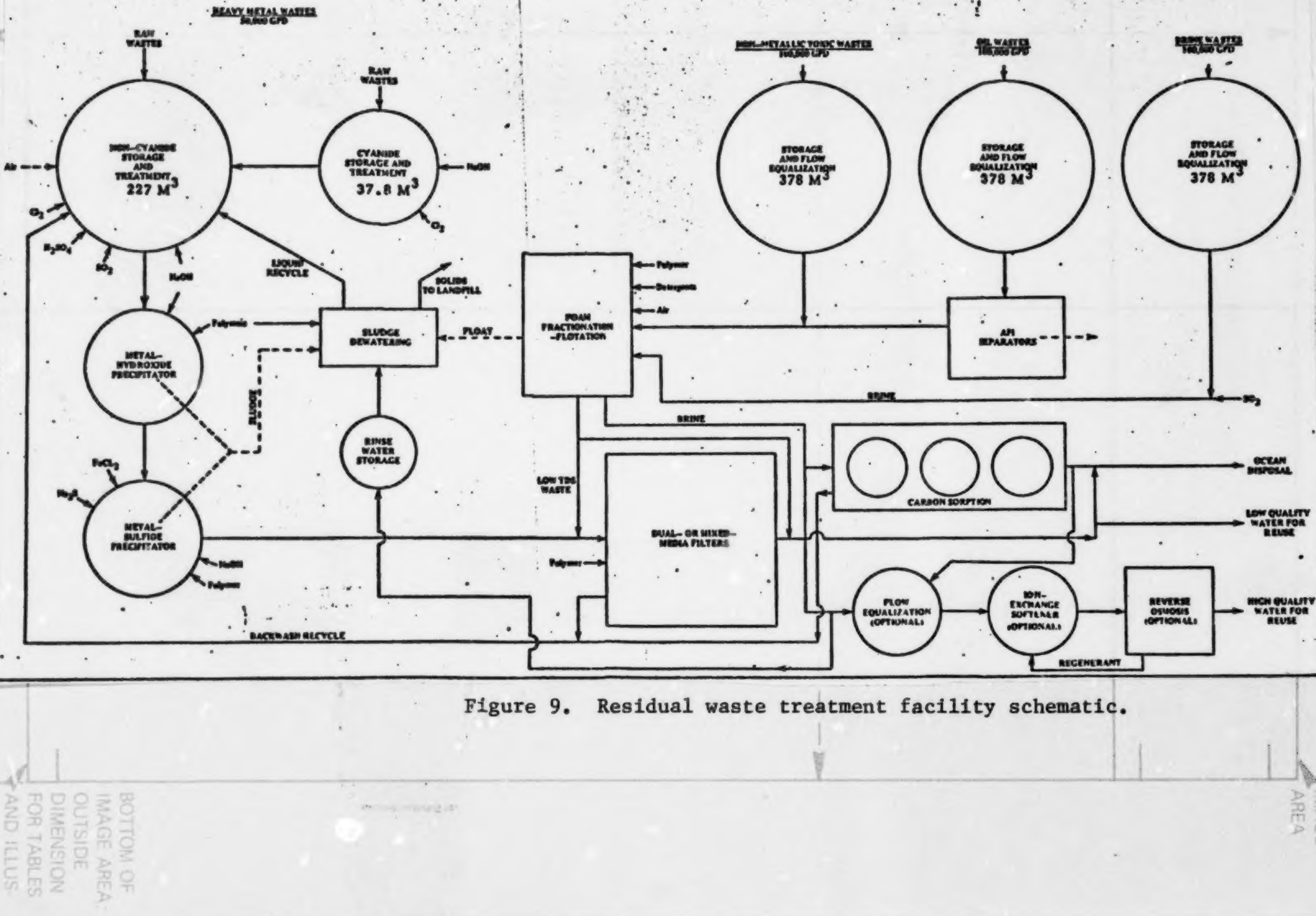
HEAVY METAL WASTES
50,000 GPD
RAW WASTES
NON-CYANIDE STORAGE AND TREATMENT 227 M^3
Air
O_2
H_2SO_4
SO_2
NaOH
RAW WASTES
CYANIDE STORAGE AND TREATMENT 37.8 M^3
NaOH
O_2
LIQUID RECYCLE
SOLIDS TO LANDFILL
Polymer
SLUDGE DEWATERING
FLOAT
METAL-HYDROXIDE PRECIPITATOR
SLUDGE
RINSE WATER STORAGE
$FeCl_2$
Na_2S
METAL-SULFIDE PRECIPITATOR
NaOH
Polymer
BACKWASH RECYCLE
NON-METALLIC TOXIC WASTES
100,000 GPD
STORAGE AND FLOW EQUALIZATION 378 M^3
OIL WASTES
100,000 GPD
STORAGE AND FLOW EQUALIZATION 378 M^3
BRINE WASTES
100,000 GPD
STORAGE AND FLOW EQUALIZATION 378 M^3
Polymer
Detergents
Air
FOAM FRACTIONATION -FLOTATION
API SEPARATORS
BRINE
SO_2
BRINE
LOW TDS WASTE
Polymer
DUAL- OR MIXED-MEDIA FILTERS
CARBON SORPTION
OCEAN DISPOSAL
LOW QUALITY WATER FOR REUSE
FLOW EQUALIZATION (OPTIONAL)
ION-EXCHANGE SOFTENER (OPTIONAL)
REVERSE OSMOSIS (OPTIONAL)
HIGH QUALITY WATER FOR REUSE
REGENERANT

Figure 9. Residual waste treatment facility schematic.

combine these units so that carbon sorption would be achieved in the filters by replacing their media with granular activated carbon.

Effluent from the foam fractionation unit during treatment of the brine wastes would be treated by carbon sorption and disposed of to the ocean through the Oxnard ocean outfall disposal system.

Bench-Scale Testing Program

The objectives of the Bench-Scale Testing Program (SBTP) are to demonstrate that the proposed treatment schemes presented in the previous section are effective on Ventura County residual wastes and to establish design criteria for prototype treatment facilities. The objectives do not include exhaustive investigation of any treatment that may be needed to reorder all wastes sampled to a quality that may be discharged to the environment or a domestic collection system. There may, therefore, exist some residual wastes that are not completely treated by the processes studied.

At the outset of the investigation, specific problem areas regarding design of a prototype treatment were recognized. These included:

1. Determination of the relative efficiencies and effectivenesses of treating the toxic metallic waste streams that contain cyanide and/or other ligands by sulfide precipitation or ion exchange.

2. Determination of the feasibility and treatment efficiencies of a foam fractionation-flotation combined process for treating nonmetallic toxic wastes and oily wastes.

3. Characterization of the sludges from the various treatment processes and determination, from fundamental studies, of the sludge dewatering/thickening devices that would be adequate for the residual waste treatment facility.

4. Determination of the requirements for and efficiencies of the final filtration and sorption processes, to be sure that the facility would meet the requirements of the EPA and the State of California.

5. Discovery of the idiosyncracies of the various residual wastes generated by selected business establishments in Ventura County and adaptation of the general treatment scheme to specific wastes.

As a yardstick in measuring the adequacy of treatment processes operating on a residual wastes, the California Ocean Plan requirements were set as preliminary treatment criteria. It was recognized that these requirements are very stringent but, if met, would ensure safe disposal of the process effluent into the marine environment.

After conducting several of the initial bench-scale laboratory tests, it became obvious that the requirements of the Ocean Plan could not be readily met by pretreatment processes considered to be economically feasible. In view of this, it was considered necessary to take advantage of the dilution in the Oxnard sewerage system and lower the pretreatment effluent quality

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objectives to those goals promulgated in Champer 25 of Ordinance No. 1510 of the City Council of the City of Oxnard. These latter guidelines as well as those of the Ocean Plan are summarized in Table 3. Of course, each of these lists of criteria is subject to change by the City, the State Board, or the EPA.

Sampling Program--

For meaningful laboratory development of industrial waste treatment processes, it is necessary to obtain a description of the processes producing the wastes, as well as representative samples of the wastes themselves. Results of earlier surveys of Ventura County industries were available at the onset of the BSTP but were, of course, not adequate for the purpose of selecting samples from appropriate sources. Furthermore, not all of the business establishments had yet agreed to supply the samples or the detailed descriptions of their waste generating operation.

Project personnel then visited selected establishments from which samples might be taken and carried out a sampling campaign. The information gathered during those visits is presented in a subsequent section under the discussion of waste characteristics.

A total of 39 samples of wastes were collected from nine industrial establishments, as summarized in Table 4. Some of the sources were resampled as the work progressed.

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Testing Program Plan--

In visiting the various establishments that generated the residual wastes, the following facts and conjectures became evident regarding those wastes:

1. Some of the wastes generated at various establishments have already been treated in one way or another; therefore, instead of treating only liquid wastes, solid phases were also encountered.

2. The wastes gathered at certain establishments were complex, incompatible mixtures of wastes, containing many phases that could not be stabilized into one phase; e.g., heavy used crankcase oil combined with pesticides, liquid and solid fertilizers, and other waste materials.

3. A wide variety, perhaps essentially all, of the toxic heavy metals would be encountered at one or more of the industrial plants in the county.

4. A wide variety, perhaps essentially all, of the toxic pesticides available for both row-crop and orchard agriculture would be encountered, usually all mixed together in waste sumps with extraneous other materials, as described in item 2 above.

5. The degree of sophistication of the chemistry utilized by the metal products plants was often high, since the plants produced high-quality, expensive products. Proprietary chemical mixtures were often used by these industrial plants, which resulted in severe problems associated with removing heavy metals from the plant wastes.

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TABLE 3. EFFLUENT QUALITY CRITERIA

Component	Concentrations Not to be Exceeded (mg/l)		
	City of Oxnard Ordinance	Ocean Plan	
		50% of Time	10% of Time
Iron	10.01	-	-
Boron	1.5	-	-
Chromium (total)	5.0	0.005	0.01
Nickel	1.0	0.1	0.2
Copper	0.5	0.2	0.3
Zinc	1.0	-	-
Lead	0.2	0.1	0.2
Mercury	0.01	0.001	0.002
Cadmium	0.10	0.02	0.03
Arsenic	1.0	0.01	0.02
Silver	-	0.3	0.5
Cyanide (CN^-)	0.2	-	-
Grease and Oil (hexane extractables)	50.0	10.0	15.0
Sulfide (dissolved)	0.1	-	-
Floating Particles	-	1.0	2.0
Toxicity Concentration (tu)	-	1.5	2.0
Toxic Substances	a	-	-
Phenolic Compounds	-	0.5	1.0
Total Identifiable Chlorinated hydrocarbons	0.5	0.002	0.004

[a] Wastes that create a hazard or interfere with treatment are prohibited.

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TABLE 4. RESIDUAL WASTE SAMPLES

Industry Designation	Sample No.	Type of Waste[a]
A	1	Settled sludge evaporation pond
	2	Plant evaporation pond influent
B	3	Washout grease oil sump (pesticides & fertilizers) subsurface sample
	4	Washout grease oil sump (pesticides & fertilizers) surface
C	5	Cutting oil sump - hydraulic oil
D	6	Annodizing sulfuric acid rinse tank
	7	Hard chrome acid
	8	Sulfuric acid type III
	9	Alkaline brass cleaner
	10	Chrome line alkaline wash rinse
	11	Copper strike - acid solution
	13	Acid copper
	14	Chromic Acid
	15	Cadmium solution, sodium cyanide
	16	Annodized sulfuric acid type II
E	17	Surface of pesticide & fertilizer sump for washouts
	18	Bottom of pesticide & fertilizer sump for washouts
F	19	Cooling tower water containing algicide
	20	Sump for plant and spray booths
	21	Sump for plant and spray booths
G	22	Dry rinse waste acid, plant sump
	23	Nickel tank dump, and same wastes as Sample No. 22
H	24	Evaporation pond subsurface
	25	Evaporation pond surface
I	26	Tank 5 cold rinse water
	27	Tank 3 cold rinse water
	28	Tank 10 cold rinse water
	29	Tank 12 cold rinse water
	30	Tank 13B cold rinse water
	31	Tank 14B cold rinse water
	32	Chromate rinse water pretreatment collection tank
	33	Chromate rinse water pretreatment with sodium hydroxide
	34	Cyanide rinse water collection tank
	35	Cyanide pretreatment with caustic soda
	36	Cyanide pretreatment with chlorine
	37	Rinse water pH neutralization collection tank
	38	Final neutralization tank
	39	Plant and pretreatment effluent

[a] Samples taken on July 6, 7, and 8, 1976 by Walter J. Bishop.

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In planning the testing program in light of these facts, it was immediately obvious that the studies aimed at determining the treatability of these wastes would be complex. The testing program plans were, therefore, not all formulated at the early stages of the project; rather, the plans were often modified as work on each sample or composite was carried out.

All of the following basic unit processes were used in the study of each sample as appropriate: cyanide oxidation, chromate reduction, ammonia removal, heavy metal precipitation, carboxylic acid ion exchange, foam fractionation-flotation, filtration, carbon adsorption, sludge dewatering/thickening, and dissolved air flotation was simulated. The emphases on the various processes and the order in which they were used was varied, as the importance of treating each sample and appropriate composites required.

Equipment, Materials and Tests--

Equipment, materials and tests employed in determining waste characteristics and the resulting most efficient treatment processes for various residual wastes are as follows:

Chemicals and glassware--Analytical reagent-grade chemicals (ACS) were used at all stages of the experimental investigation. Glassware was washed with a detergent and rinsed with tap water and deionized water. Glassware used in the preparation of standards for atomic absorption spectrometry was, in addition, soaked in 1:1 HCl, rinsed three times with tap water, and then rinsed three times with tap-deionized water.

pH measurements and potentiometric titrations--Determinations of pH were carried out by using a Sargent pH meter (Model L.S.) with glass and reference electrodes manufactured by Corning. Potentiometric titrations were carried out using the same reference electrode coupled with a platinum electrode, also manufactured by Corning.

Inorganic analyses--Heavy metal concentrations were determined by flame atomic adsorption spectrometry (AAS) using a Perking-Elmer Atomic absorption Spectrometer (Model 305B). Metal standards were prepared from commercially available 1000 mg/l standards or as specified in Standard Methods.[1] The precision of these measurements is given in Table 5.

Ammonia-nitrogen (NH_3-N) was separated by steam-distillation. The distillte, collected in a 2-percent boric acid solution, was titrated with 0.2N H_2SO_4 to the methyl red-methylene blue mixed indicator endpoint according to Standard Methods.

Organic analyses--Organic carbon was determined by utilzing a Dohrmann-Envirotech Total Organic Carbon Analyzer (Model DC-52D). The volatile organic carbon (VOC) and residual organic carbon (ROC) contents were monitored individually. The VOC and ROC comprise the total organic carbon (TOC).

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[1] Standard Methods, 14th Ed., prepared and published jointly by: American Public Health Association; American Water Works Association and Water Pollution Control Federation, Washington, D.C., 1975.

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TABLE 5. PRECISION OF AAS ANALYSIS

Metal	True Value (mg/1)	Mean $\bar{X}=\frac{\Sigma x}{N}$	Measured Value (mg/1)	Standard Deviation $S\pm\frac{\Sigma\,(x-\bar{x})^2}{N-1}$
Ag	-	-	-	-
As	278	247	153	89
Cd	73	77	70	21
Cr	406	341	424	133
Cu	314	316	299	57
Fe	769	784	754	108
Hg	-	-	-	-
Mu	449	446	425	68
Ni	-	-	-	-
Pb	350	368	349	125
Se	48	50	42	28
Fn	367	367	371	96

As the treatments progressed through the various stages, specific organic compounds present in the samples were monitored on a Varian 3700 Gas Chromatograph equipped with a flame ionization detector. Identification of the compounds were outside the scope of this project. In order to perform a gas chromatographic (GC) monitoring test, it was necessary to apply a single-stage solvent extraction technique using hexane (distilled in glass) as solvent. Extractions were performed in a 25-ml Erlenmeyer flask equipped with a Teflon spinbar. Ten ml of aqueous samples and 10 ml hexane were employed. After stirring for at least 15 minutes at the speed which gave maximum turbulence, the mixture was transferred to a centrifuge tube and spun at 1000 rpm for ten minutes in an IEC Centrifuge (Model PR-6000). After centrifugation, 1 ml of the organic phase was injected directly into a 2-mm-I.D. GC column. The column was packed with 3 percent G.E. SE-30 on 100/120-mesh Gas Chrom Q. The temperatures of the injector, column, and detector were set constant at 150°C, 200°C (isothermal), and 270°C, respectively. The flow of N_2 carrier gas was adjusted to 30 ml/min.

Coagulation procedures--There are many producers of flocculant polymers for water and wastewater treatment processes. Fortunately, many of the competitive products of similar chemical structure and molecular weight behave in a similar way; therefore one may select the one polymer that is used on a cost/performance basis. In the present work, cationic Hercofloc polymers (Hercules, Inc.) were employed, as shown in Table 6 with or without alum, $Al_2(SO_4)_3$.

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TABLE 6. HERCOFLOC POLYMERS EMPLOYED IN COAGULATION EXPERIMENTS

Hercofloc Polymer Number	Molecular Weight/ Ionic Nature	Form
81.2.3	low cationic	powder
855.0	medium-high cationic	powder
834.1	high cationic	powder

Polymer solutions were prepared by very slow addition of 1 g polymer into a beater containing 200 ml of distilled water, which was stirred on a magnetic stirrer until a distinct water vortex was formed. The speed of mixing was coninuously increased during the powder addition to maintain the water vortex. The mixing was continued at a moderate speed for 1 hour after the addition of polymer was completed.

The coagulation experiments were performed by placing 700 ml samples in 1-l Pyrex beakers on a Phipps-Bird gang-stirrer, as shown in Figure 10. The paddles, each 3" x 1", were immersed to within 2 1/4" of the bottom of the mixing beaker. pH values were adjusted to 7.5. The gang-stirrer was operated at 120 rpm, and polymer (with alum if required) was added. Fast stirring was continued for 1 minute after polymer addition, then reduced to simulate the action of a flocculation basin.

The optimum coagulation dose was determined according to the standard refiltration rate procedure using a Millipore filtration apparatus. A sample (25 ml) of each of the coagulated suspensions was filtered through a 0.45-micron (u) Millipore filter using a controlled vacuum of exactly 17 inches of mercury (Hg). Each filtrate was collected and refiltered through the filter cake and 0.45-u filter. The time of refiltration was recorded.

When coagulating nonmetallic toxic wastes, turbidity was measured (using a Hach Turbidity Meter (Model 2110), while simultaneously determining the optimum polymer dose by the refiltration rate method. Prior to sampling the supernatant for determination of turbidity, 30 minutes settling was allowed. Floc characteristics were determined by visual observations.

Foam Fractionation-flotation experiments--In order to simulate the foam fractionation-flotation unit operations, it was necessary to construct suitable equipment. Air flotation and foam fractionation both involve the generation of air bubbles. Since using the two processes simultaneously is a new concept, some basic principles are discussed in the next section.

1. Design criteria for foam fractionation-flotation device

In air flotation the bubbles attach themselves to particulate matter, thereby increasing buoyancy. In foam fractionation, soluble surface-active materials are absorbed on the surfaces of foams. The foams are generated above the liquid phase, the transformation from bubbles to foam occurring when

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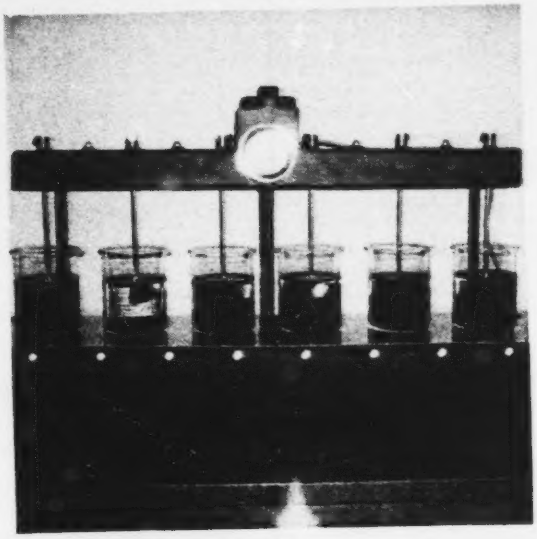

Figure 10. Experimental Set-up for coagulation experiments

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the air leaves the liquid pool to form a foam above it. Air flotation and foam fractionation may occur simultaneously. In fact, surface-active agents are sometimes added in an air flotation apparatus so as to attach surfactant molecules to the solids to be floated.

Most flotation cells presently operated for waste treatment are of the dissolved air type. Their operation depends upon dissolving air under pressure into the waste stream to be treated. Once released to atmospheric pressure, much of the dissolved air comes out of solution and carries the suspended solids to the surface as the bubbles rise. Most of these cells are designed for horizontal flow of both the water and the float solids, and surface skimmers are used to convey the floated solids to one end or the other of the cell, where they are removed.

In recent years, a more rational approach to flotation apparatus design has been developed. This type of design, which is available commercially, is illustrated schematically in Figure 11. This schematic does not differ in principle from classical foam fractionation devices, except that air spargers instead of dissolved air are used. There are four alternative modes of continuous-flow operation with a foam fractionation column as illustrated schematically in Figure 12.

The foam fractionation-flotation process employs countercurrent flow of solution containing foaming agents, by air sparged at the bottom of the column. It has been demonstrated to be effective in removing colloids and other particulates from agricultural drainage waters. It can, remove organic matter, including substantial quantities of oils with appropriate polyelectrolyte aids. The clarified effluent usually comprises approximately 95 percent of the feed volume and is essentially high-quality water. For further purification, filtration or sedimentation can be provided as subsequent treatments. If small traces of organic constituents are still present and unacceptable, the effluent may also be treated by activated carbon sorption.

The bench-scale model built for this study took all of these design requirements and factors into account. A drawing of the device is shown in Figure 13. Foam breaks off from the plastic tee on the right side of the apparatus and falls into a collector below. In order to operate the apparatus optimally, it was necessary to determine which of the four possible modes of operation should be employed. It was also necessary to optimize flow rates of air, feed, and effluent and the ratio of the height of the liquid pool to the height of the foam column. The latter optimization controls the foam dryness, which, in turn, determines the volume of collapsed foam. The collapsed foam should, of course, constitute the smallest practicable volume commensurate with removing the required portion of contaminants.

2. Operation criteria for foam fractionation-flotation

None of the wastes foamed sufficiently for operation without a detergent. Hence, it was necessary to choose the best detergent for promoting the foaming phenomenon, to choose the appropriate operating mode, and to choose appropriate analytical methods compatible with the choice of detergent. Also, the question of employing flotation aids and/or coagulants needed to be considered.

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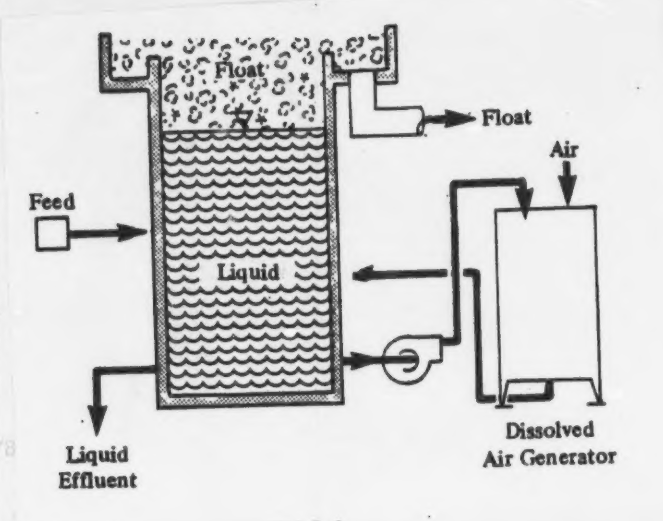
Float
Float
Air
Feed
Liquid
Liquid Effluent
Dissolved Air Generator

Figure 11. Continuous flotation schematic.

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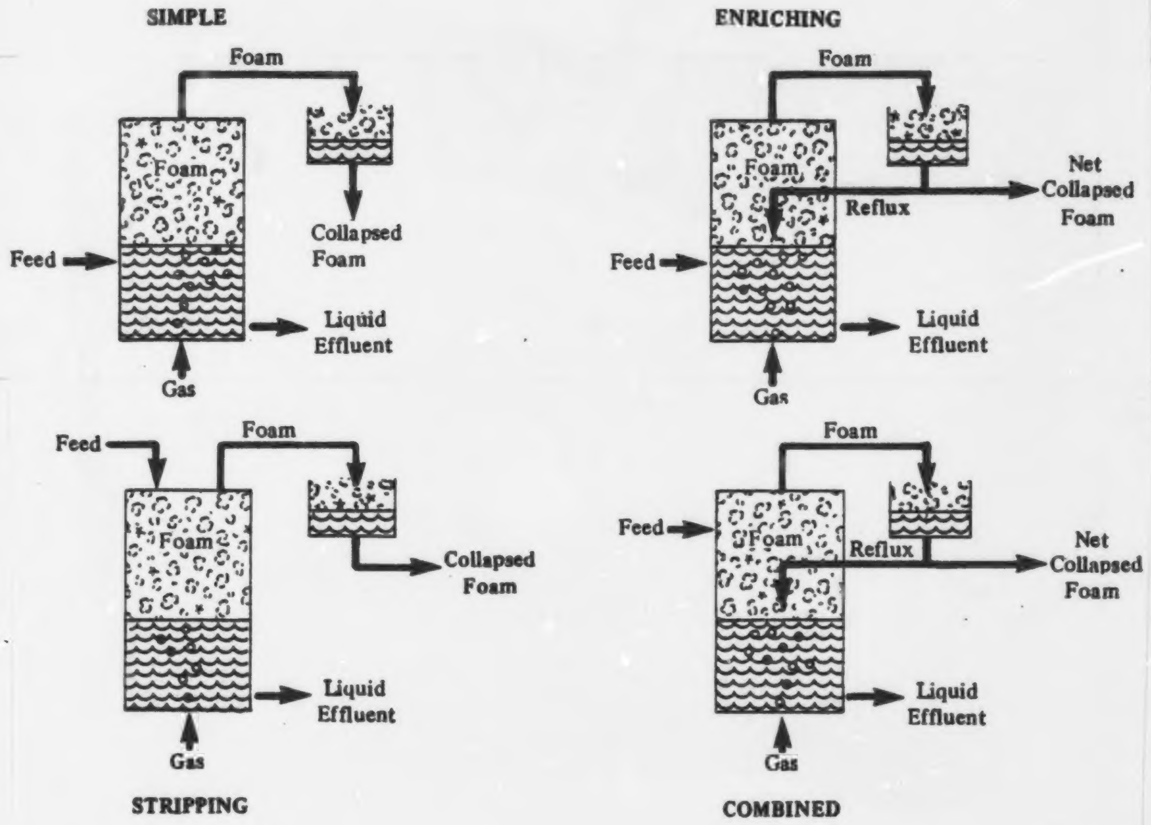
SIMPLE
Foam
Foam
Feed
Collapsed Foam
Liquid Effluent
Gas
ENRICHING
Foam
Foam
Reflux
Net Collapsed Foam
Feed
Liquid Effluent
Gas
Feed
Foam
Foam
Collapsed Foam
Liquid Effluent
Gas
STRIPPING
Foam
Feed
Foam
Reflux
Net Collapsed Foam
Liquid Effluent
Gas
COMBINED

Figure 12. Modes of operation of various foam fractionation systems.

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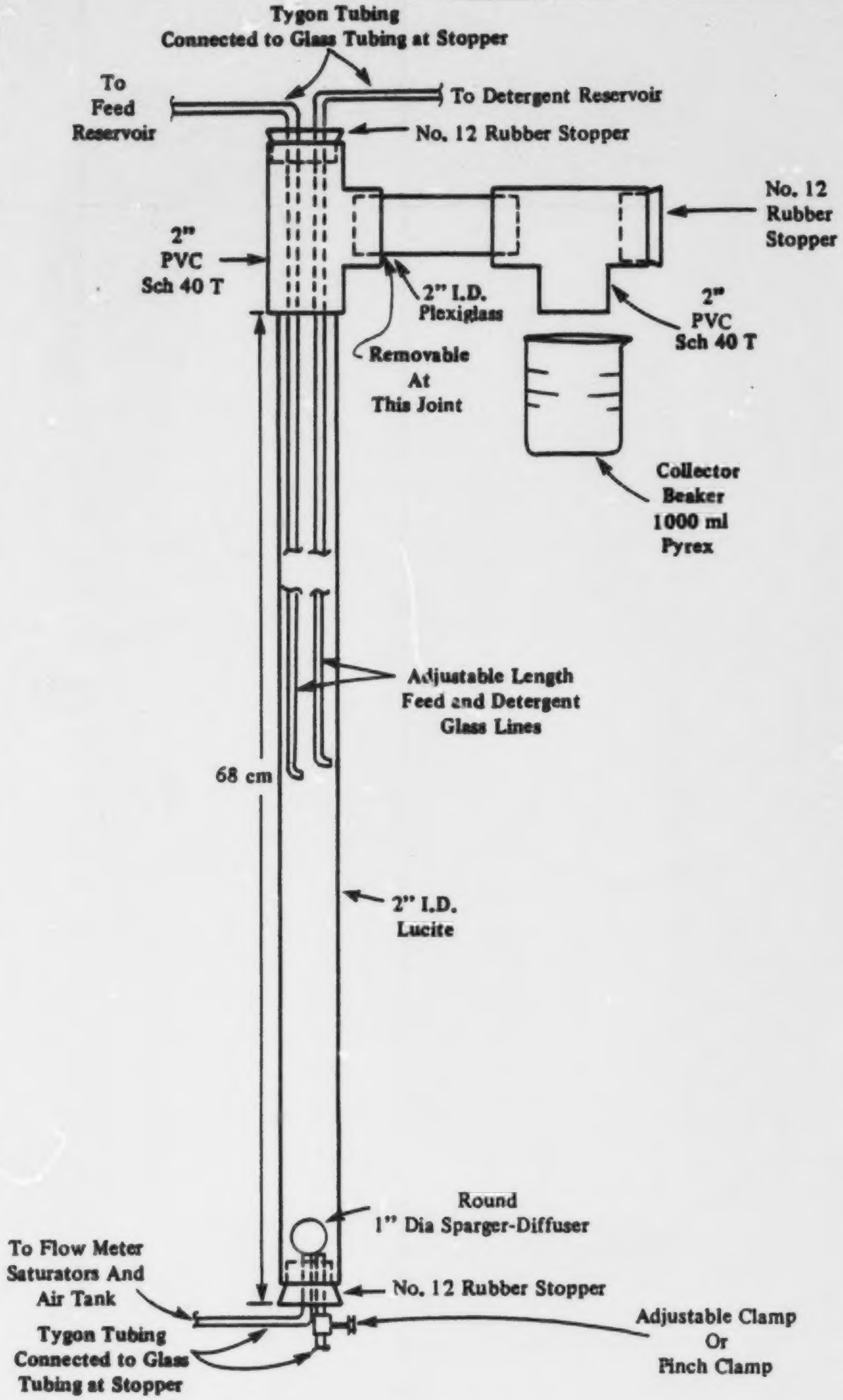
Tygon Tubing
Connected to Glass Tubing at Stopper
To Feed Reservoir
To Detergent Reservoir
No. 12 Rubber Stopper
No. 12 Rubber Stopper
2" PVC Sch 40 T
2" I.D. Plexiglass
2" PVC Sch 40 T
Removable At This Joint
Collector Beaker 1000 ml Pyrex
Adjustable Length Feed and Detergent Glass Lines
68 cm
2" I.D. Lucite
Round 1" Dia Sparger-Diffuser
To Flow Meter Saturators And Air Tank
No. 12 Rubber Stopper
Adjustable Clamp Or Pinch Clamp
Tygon Tubing Connected to Glass Tubing at Stopper

Figure 13. Bench-scale fractionation-flotation device.

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The detergent products manufactured by Onyx Chemical Company were examined. Discussions with Onyx personnel and subsequent experiments with three Onyx formulations (Maprofix SP, Maprofix WAS, Neutronyx 656) and one of the Onyx foam boosters (Ammonyx LO), as well as two other detergents from other manufacturers, led to the selection of Maprofix SP. This decision was based on the fact that Maprofix SP could be used in very low concentrations (0.01 percent); and produced a very dry foam in batch experiments with all the samples tested and a large number of visual observations indicated that no other combination of operating techniques and detergent produced the desired results on every sample.

The concentrations of detergent added to the samples of wastes were determined using the methylene-blue method for surfactants as outlined in Standard Methods. The concentration of organic carbon present was determined by the TOC analyzer already described. Owing to the presence of the detergent added during the treatment process, this measured value consisted of C detergent +C nondetergent. After subtracting the value C detergent, obtained by the methylene blue method, concentrations of C nondetergent were determined.

In the unit the rate of aeration was such that the foam rose slowly enough to drain completely before it entered the neck of the apparatus leaving the collector. Foaming was continued until insufficient foam was generated to force the overlying foam to the top of the apparatus. A sample was then withdrawn from the liquid remaining in the apparatus, and another 0.01 percent increment of detergent solution was added. The process was repeated as necessary.

Settling Tests--A 2.5-cm-I.D. Lucite tube, 160 cm long, was used for the tests on the settling characteristics of sludges produced at various stages of the treatment of residual wastes. Settling tests were performed with the tube upright at a 60° angle (measured from horizontal).

Filtration Column--The filter column was made of Lucite, 2.5-cm-I.D. The packings, which were supported on glass wool, consisted of 35 cm of anthracite (effective size + 1.3 mm, uniformity coefficient = 1.37, specific gravity = 1.64) and 75 cm of sand (effective size = 0.64 mm, uniformity coefficient = 1.52, specific gravity = 2.61).

Carbon Adsorption Column--A round glass column, (4.5 cm I.D.), was packed with 35 cm of activated carbon (4-12 mesh granular, Matheson Coleman and Bell) supported on a sintered glass disc of high porosity.

Carboxylic Cation Exchange Column--A Lucite tube (2.5 cm I.D., 15.6 cm long) was packed with 100 cm of carboxylic acid ion exchange resin obtained from the Permutit Company (Permutit designation Q-205). This resin is equivalent for all practical purposes to Amberlite IRC-84, a weakly acidic carboxylic cation exchange resin.

The resin was received in the H-form and was transferred to the Na-form by treatment in the column with 15 percent NaOH and rinsed with double-distilled water in accordance with the manufacturer's recommendation. Employment

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of this particular resin in the acid form with the highly basic solutions, from which heavy metals were to be removed, would have caused at least two complicating factors, neither of which would have been desirable. These factors are: (a) a very large hat of reaction of the sample with the resin and (b) a very large expansion of the resin. Both of these factors would have caused a variation in the flow rate during the experiments and, perhaps, would have affected the results. In practice, heavy metals are often removed using carboxylic resins in the salt form, although regeneration requires two steps: (1) acid regeneration and (2) conversion of the acid from resin to the sodium form using a basic material.

As shown subsequently, the precipitation of heavy metals with the bases and with sulfides requires that each toxic metallic waste be considered separately; therefore, no general description of these procedures is given.

Waste Characteristics--

For the purpose of this study, wastes were characterized by the chemical response to certain possible treatment processes. During this section of the study, it was important to determine the particular responses of the type of wastes encountered in Ventura County to the described treatment processes. As a result, the end products of many of the tests reported in this chapter do not represent the optimum treatment performance attainable from each of the processes but provide chemical information for developing treatment schemes. It frequently became necessary to use methods in studying this chemistry that would not necessarily be used in the finally adopted treatment processes. This assisted the investigators in getting required information about certain specific treatment sequences. These points will be made clear as the details of this and the next chapter are presented.

The first characteristics of the wastes tested were identified after reviewing the sources from which the samples came. Each industry sampled was questioned as to the nature of the waste, processes used in the production of the waste, and other types of extraneous materials that might have been added to the waste prior to the sample pickup. Many industries were able to name most of the constituents in the wastes that were preventing them from discharging into municipal systems or directly to the environment.

Industrial cooperation in this project was found to be generally good. Part of this cooperation was gained from industry by assuring them that the information obtained would be treated in a confidential manner. As a result, the names, addresses, and specific designations of industries from which samples have been obtained have been omitted from this publication. Instead, a code has been adopted for each of the industries; for example, Industry A, Industry B, etc. A complete listing of the coded industries sampled is provided in Table 4. The following sections are not completely sequential, as shown in this table, because of the varying nature of the waste. For example, Industry D follows Industry A because samples from B and C do not contain heavy metals, and these were the analyses conducted first.

Industry A--Industry A does not have a large volume of liquid waste. Its processes involve the collection of aluminum and magnesium scraps and the conversion of these scraps into recyclable aluminum and magnesium "pigs,"

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which are marketed similarly to the virgin metals. Certain alloys which are brought in as raw material contain certain heavy metal impurities, e.g., copper and zinc, which are removed normally as "dross." Industry A used KCl and $MgCl_2$ as fluxes which together with the dross end up as an aqueous slurry in a pond where the water is evaporated. The samples taken were:

No. 1	Settled sludge from the evaporation ponds
No. 2	Plant evaporation pond influent

Each of the samples contains solids and liquids. The solids were gray and black, very dense, with finely divided particulates. The influent sample (No. 2) did not appear to be as representative of the kind of constituents that might be found in the wastes emitted from the operation over a long period of time as did the settled sludge sample. Nevertheless, both samples in a 1:1 mixture of the tube are examined in accordance with the flow schemes indicated in Figure 14.

Laboratory experiments were aimed at determining the effluent quality obtained by hydroxide precipitation plus sulfide precipitation under the condition that the sludges in each sample would first be leached with boiling hydrochloric acid. The leaching was carried out for 20 minutes at the boiling temperature after the mixed sample had remained overnight in the HCl solution at ambient temperature. Leaching was expected to dissolve any heavy metal compounds persent in the effluent which over a long period of time may have precipitated because of evaporation. Even under these extreme conditions, the final effluent did not contain high concentrations of any of the heavy metals examined.

Industry D--Industry D is a custom plating firm that specializes in plating small parts on a subcontract basis for larger firms. Although the plating plant appears antiquated, an interview with plant personnel indicated that the firm performed a modern, sophisticated operation, and the plant employs many toxic metallic substances and ligands in its procedures. Eleven samples were taken in Industry D (numbered 6 through 16), as follows:

Sample No.	Description	pH
6	Anodizing sulfuric acid rinse tank	6.5
7	Hard chrome acid	0.5
8	Sulfuric acid type II	0.3
9	Alkaline brass cleaner	10.5
10	Chrome line alkaline wash rinse	6.85
11	Copper strike - acid solution	10.4
12	Bright nickel	5.2
13	Acid copper	1.2
14	Chromic acid	1.0
15	Cadmium solution, sodium cyanide	12.5
16	Anodized sulfuric acid type II	0.5

After reviewing all of the samples taken, Sample No 15 was set aside since it obviously contained cyanides and would require cyanide destruction.

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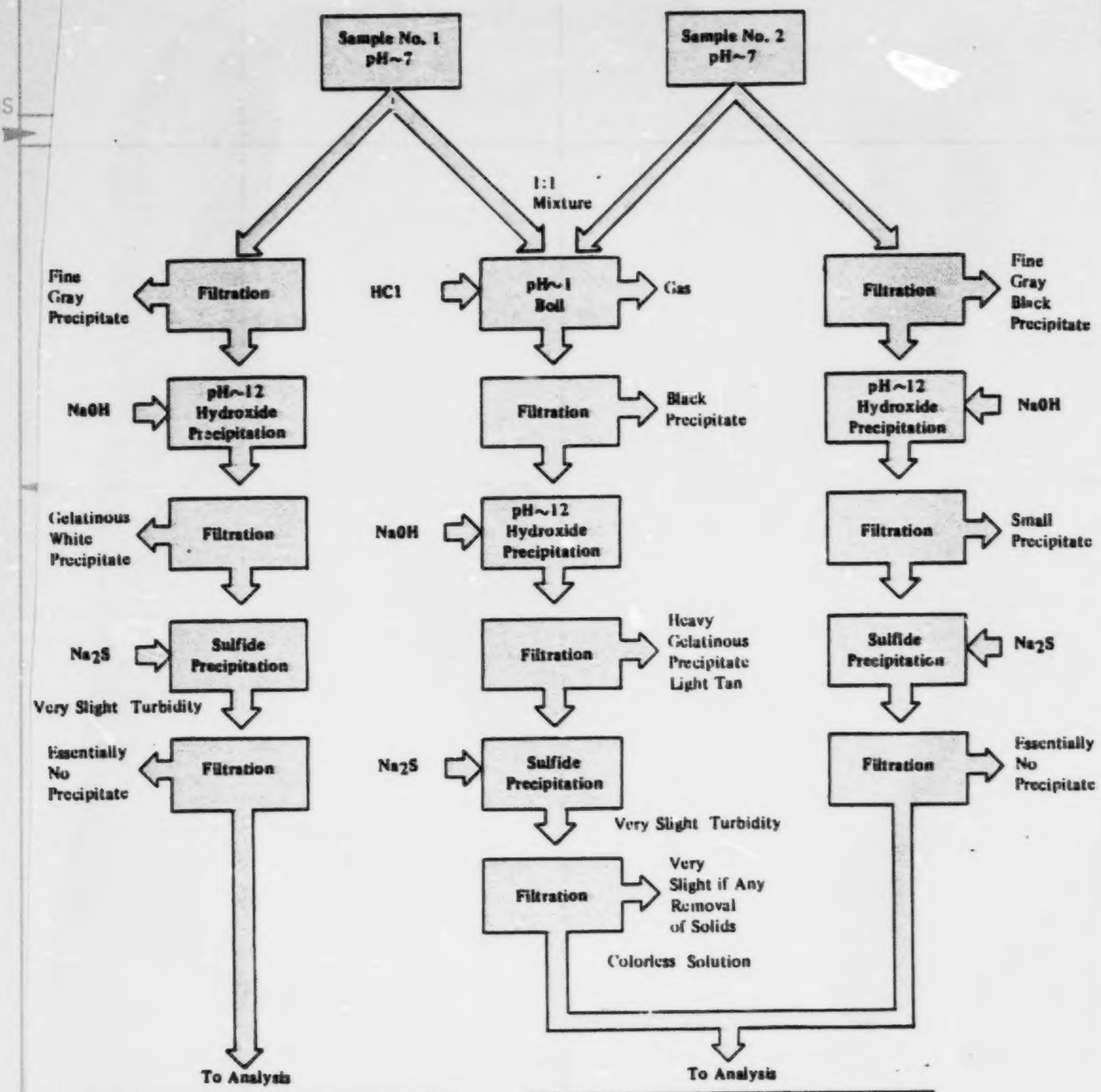
Sample No. 1
pH~7
Sample No. 2
pH~7
1:1
Mixture
Fine
Gray
Precipitate
Filtration
HC1
pH~1
Boil
Gas
Filtration
Fine
Gray
Black
Precipitate
NaOH
pH~12
Hydroxide
Precipitation
Filtration
Black
Precipitate
pH~12
Hydroxide
Precipitation
NaOH
Gelatinous
White
Precipitate
Filtration
NaOH
pH~12
Hydroxide
Precipitation
Filtration
Small
Precipitate
Na2S
Sulfide
Precipitation
Filtration
Heavy
Gelatinous
Precipitate
Light Tan
Sulfide
Precipitation
Na2S
Very Slight Turbidity
Essentially
No
Precipitate
Filtration
Na2S
Sulfide
Precipitation
Filtration
Essentially
No
Precipitate
Very Slight Turbidity
Filtration
Very
Slight if Any
Removal
of Solids
Colorless Solution
To Analysis
To Analysis

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.03	0.025	0.06	0.15	0.03	0.04	0.06	0.02

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.115	0.035	0.105	0.575	0.06	—	0.28	0.5

Figure 14. Industry A, engineering waste characteristics.

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Of the remaining ten samples, 20 ml of each, except for Samples Nos. 13 and 14, were mixed. Samples Nos. 13 and 14 were obviously very concentrated and required only 5 ml to be mixed. The composite of the mix was believed to be more representative of the type of residual waste which would have to be diposed from this operation. This composite was then subjected to waste characteristics determination without cyanide destruction as indicated in Figure 15.

When the composite was mixed, gas was given off. This could have been HCN, since spent alkaline brass cleaners usually contain excess inorganic ligands that are used to speed up the cleaning operation. Therefore, when the cleaner was mixed with the other predominantly acid samples, a small amount of HCN may have escaped. The amount of HCN gas which could escape would be limited because of the reaction of most of the excess of CN^- in the cleaner with excess heavy metal ions from the other samples. Chromium in the hexavalent state was obviously present in Sample No. 14. It was reduced in the composite to chromic ion followed by precipitation of Cr^{3+} as $Cr(OH)_3$. The other heavy metals in the composite were substantially precipitated in the form of the respective hydroxides in this operation. After filtration, the filtrate was precipitated with Na_2S, and the steps shown in Figure 15 were carried out.

The analysis of the filtrate from the series of operations showed inacceptable concentrations of copper, lead, and nickel. (In view of the high pH values, Samples Nos. 9 and 11, cyanide and cyanate destruction on each was carried out and followed potentiometrically.) The potentiometric titration curves indicated that Sample No. 9 contained some cyanide but Sample No. 11 may have contained only small proportions. As will be discussed subsequently, it was considered necessary to treat the entire Industry D composite for cyanide destruction. This was the first indication that essentially all heavy metals samples entering a residual waste treatment facility should be assumed to contain cyanides or other ligands.

Sample No. 15 was examined to determine its treatment characteristics separately, (see Figure 16). Potentiometric titrations with NaOCl, as indicated in Figure 17, proved the presence of cyanides. After completion of their oxidation, the resulting suspension was treated from chromium reduction. Following the addition of ferrous sulfates, the suspension was split in two parts to determine whether the excess $Fe(OH)_2$ formed should be removed by filtration. The first part (Sequence I) was filtered, and the metals in the resulting filtrate were precipitated using Na_2S. The metals in the other part (Sequence II) were precipitated using Na_2S without prior removal of hydroxides by filtration. Residual concentrations of heavy metals in the effluents from both sequences were of the same order of magnitude. This lead to the conclusion that the hydroxide precipitate of the added $FeSO_4$ did not interfere with the sulfide precipitation of the toxic heavy metals. However, the iron concentration was higher in the final filtrate when the $Fe(OH)_2$ was not removed by filtration.

Industry G--Industry G is a solid-state electronics components manufacturing establishment. The interview with plant personnel did not reveal any information concerning the actual plant operation. Two samples were

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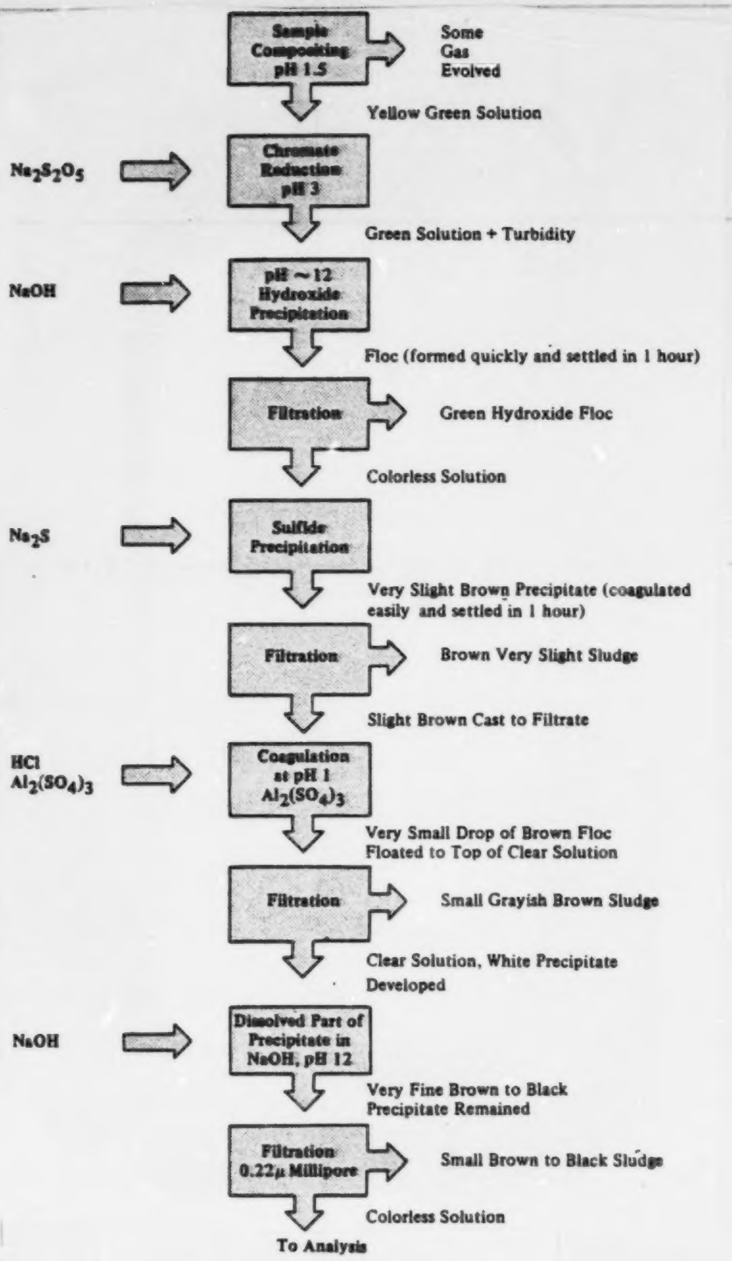
Sample Compositing pH 1.5
Some Gas Evolved
Yellow Green Solution
$Na_2S_2O_5$
Chromate Reduction pH 3
Green Solution + Turbidity
NaOH
pH ~12 Hydroxide Precipitation
Floc (formed quickly and settled in 1 hour)
Filtration
Green Hydroxide Floc
Colorless Solution
Na_2S
Sulfide Precipitation
Very Slight Brown Precipitate (coagulated easily and settled in 1 hour)
Filtration
Brown Very Slight Sludge
Slight Brown Cast to Filtrate
HCl
$Al_2(SO_4)_3$
Coagulation at pH 1 $Al_2(SO_4)_3$
Very Small Drop of Brown Floc Floated to Top of Clear Solution
Filtration
Small Grayish Brown Sludge
Clear Solution, White Precipitate Developed
NaOH
Dissolved Part of Precipitate in NaOH, pH 12
Very Fine Brown to Black Precipitate Remained
Filtration 0.22μ Millipore
Small Brown to Black Sludge
Colorless Solution
To Analysis

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
~3.5	0.095	0.145	1.74	0.27	0.19	1.58	1.4

Figure 15. Industry D, waste characteristics, composite of samples no. 6 through no. 16 except no. 15.

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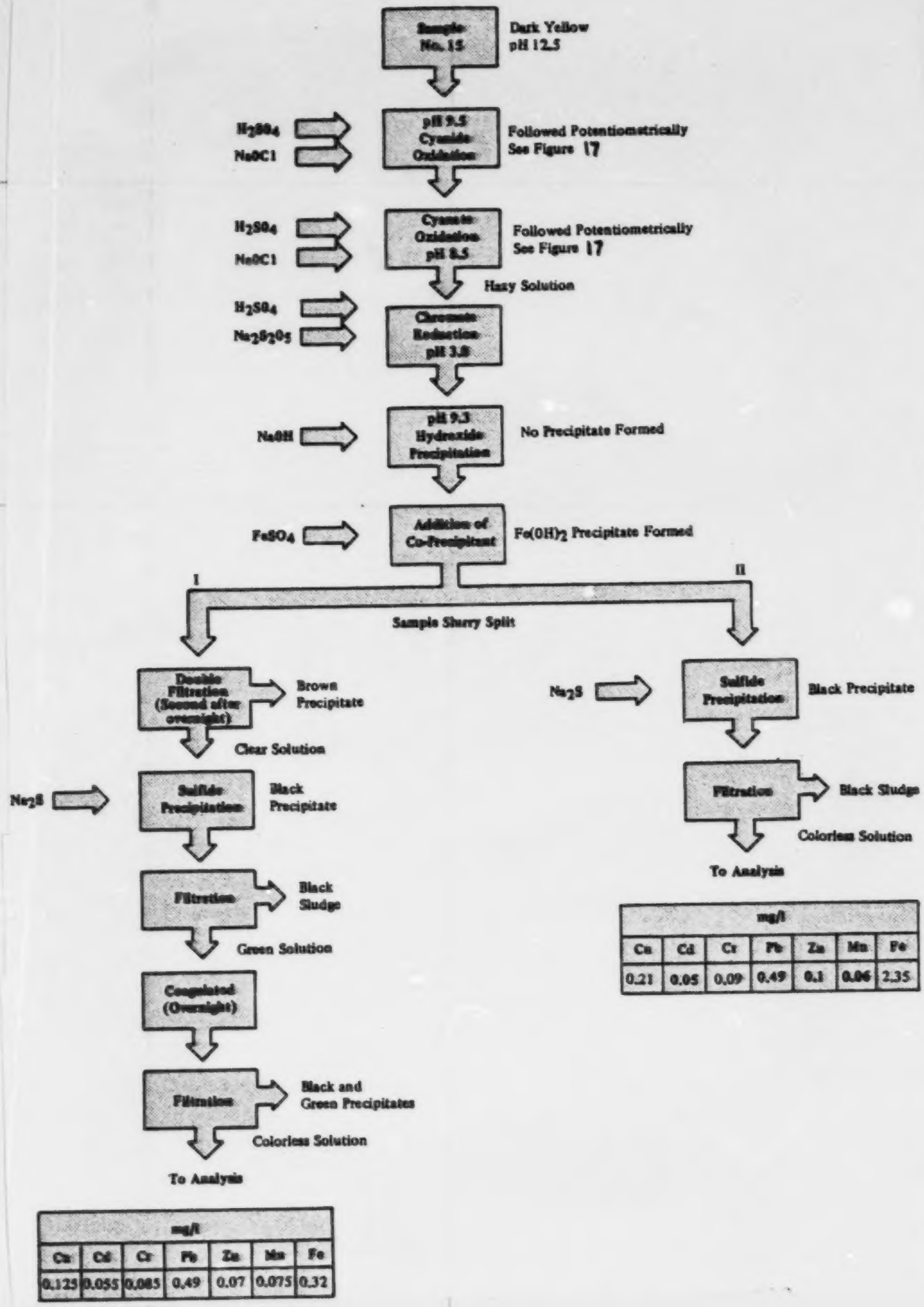
Sample No. 15
Dark Yellow
pH 12.5
H_2SO_4
NaOCl
pH 9.5
Cyanide Oxidation
Followed Potentiometrically
See Figure 17
H_2SO_4
NaOCl
Cyanate Oxidation
pH 8.5
Followed Potentiometrically
See Figure 17
Hazy Solution
H_2SO_4
$Na_2S_2O_5$
Chromate Reduction
pH 3.8
NaOH
pH 9.3
Hydroxide Precipitation
No Precipitate Formed
$FeSO_4$
Addition of Co-Precipitant
$Fe(OH)_2$ Precipitate Formed
I
II
Sample Slurry Split
Double Filtration (Second after overnight)
Brown Precipitate
Clear Solution
Na_2S
Sulfide Precipitation
Black Precipitate
Filtration
Black Sludge
Green Solution
Coagulated (Overnight)
Filtration
Black and Green Precipitates
Colorless Solution
To Analysis
Na_2S
Sulfide Precipitation
Black Precipitate
Filtration
Black Sludge
Colorless Solution
To Analysis

mg/l						
Cu	Cd	Cr	Pb	Zn	Mn	Fe
0.21	0.05	0.09	0.49	0.1	0.06	2.35

mg/l						
Cu	Cd	Cr	Pb	Zn	Mn	Fe
0.125	0.055	0.085	0.49	0.07	0.075	0.32

Figure 16. Industry D waste characteristics, sample no. 15.

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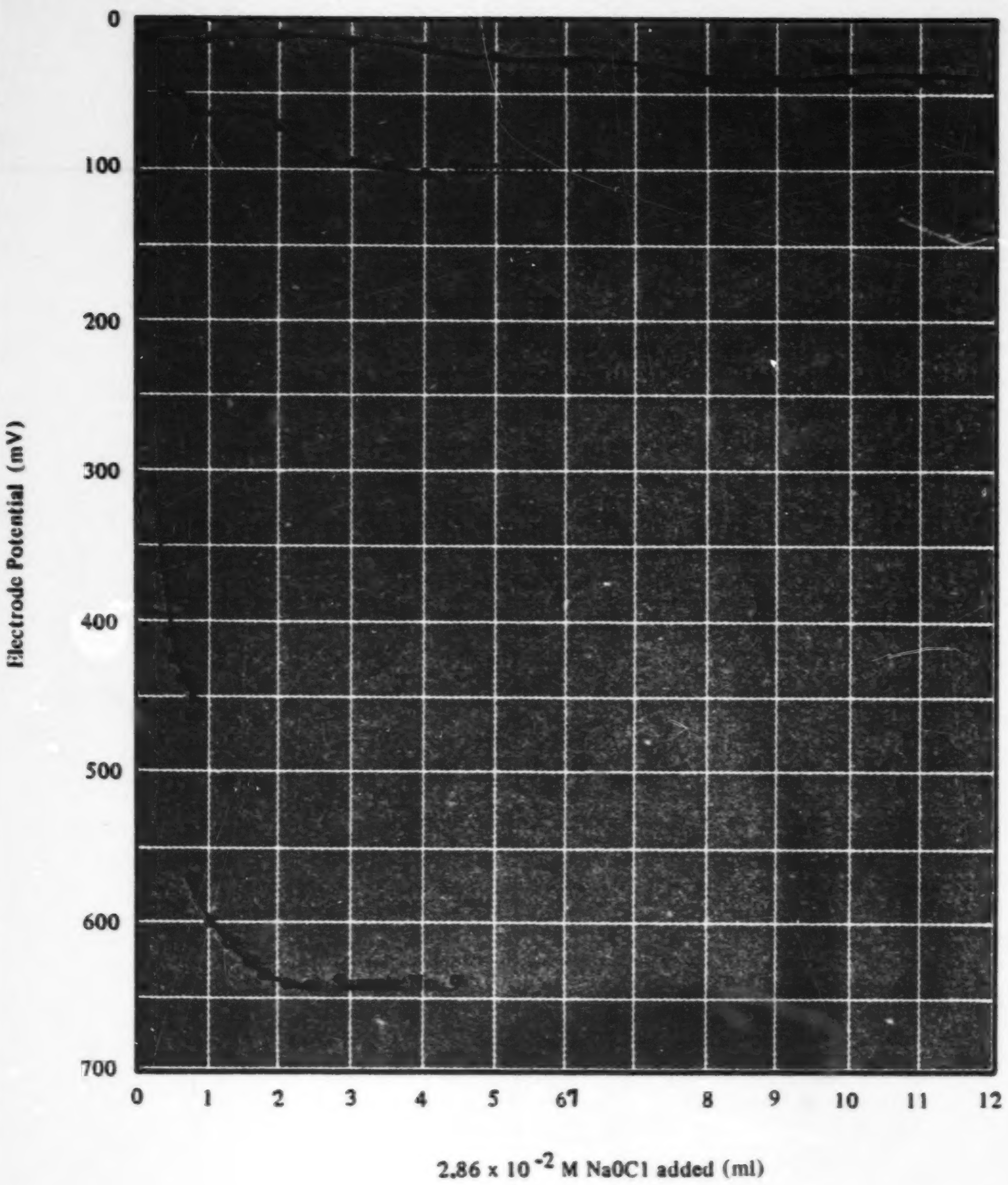

Figure 17. Oxidation of cyanides and cyanates with NaOCl in three samples from industry D.

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taken and labeled as follows:

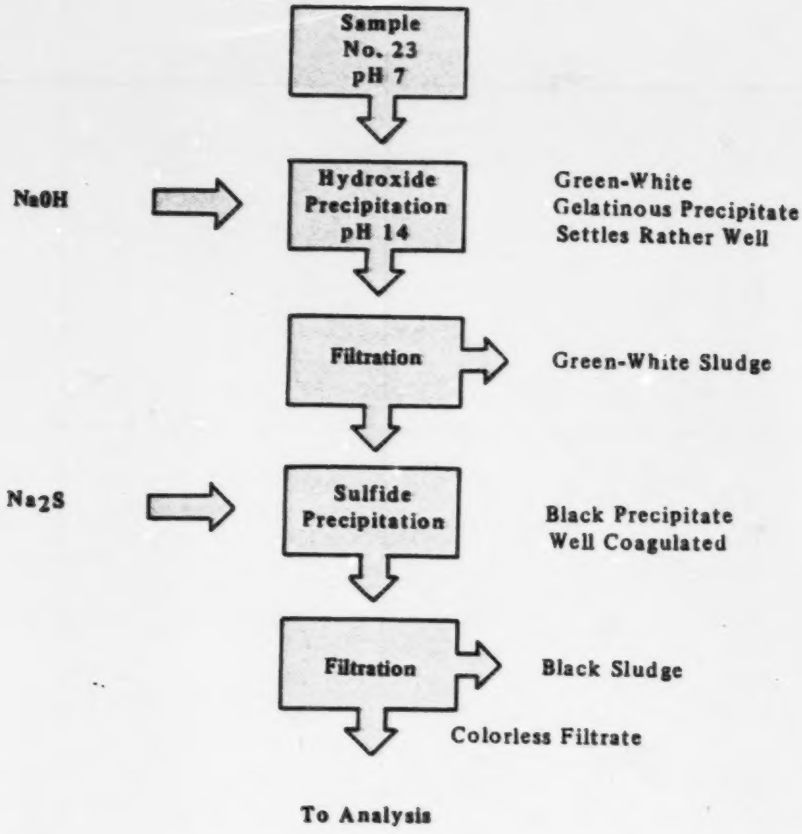
No. 22	Dry rinse waste acid plant sump
No. 23	Nickel tank pump combined with dry rinse waste acid plant sump

For the purpose of determining waste characteristics, only Sample No. 23 was examined, since it represented the total wastes from the plant. The hydroxide precipitation and sulfide precipitation processes were tested with Sample No. 23 in the manner shown in Figure 18. Analysis of the final filtrate resulting from the hydroxide and sulfide precipitation of heavy metals showed that quite high concentrations of nickel, copper, and zinc were present. Subsequent to the analysis, the industry submitted a flow diagram which indicated that nickel and copper were the metals of interest likely to be present in high concentrations in their wastes. Silver is also involved in Industry G's processing work but is recovered as AgCl. Wastes in the collection tank at Industry G were neutralized by addition of ammonia. The presence of ammonia would definitely account for the high residual concentrations of nickel, copper, and zinc, since these metals are known to form strong complexes from ammonia. In order to decrease the concentration of these metals in the final effluent, it would be necessary to break these complexes with a strong base and remove ammonia by sparging. This sequence may not remove all the ammonia completely, and oxidation to break-point chlorination would be required, as shown in Figure 5.

Industry I--Industry I is a producer of high-quality fasteners for aircraft service. Typically, the fasteners are made of carbon steel which is formed in dies, assembled in dies, cadmium-plated in an electrical-chemical bath containing cyanides, then surface-treated with hexavalent chromium and a molybdenum compound. The manufacturing plant includes a waste treatment facility designed specifically to destroy cyanides, reduce hexavalent chromium, and precipitate heavy metals as the hydroxides.

Industry I furnished 14 samples from various tanks used in this production line and from its waste treatment plant. The samples are described as follows:

No. 26	Tank 5 cold rinse water
No. 27	Tank 8 cold rinse water
No. 28	Tank 10 cold rinse water
No. 29	Tank 12 cold rinse water
No. 30	Tank 13B cold rinse water
No. 31	Tank 14B cold rinse water
No. 32	Chromate rinse water pretreatment collection tank
No. 33	Chromate rinse water pretreatment with sodium hydroxide
No. 34	Cyanide rinse water collection tank
No. 35	Cyanide pretreatment with caustic soda
No. 36	Cyanide pretreatment with chlorine
No. 37	Rinse water pH neutralization collection tank
No. 38	Final neutralization tank
No. 29	Plant and pretreatment effluent


Sample
No. 23
pH 7
NaOH
Hydroxide
Precipitation
pH 14
Green-White
Gelatinous Precipitate
Settles Rather Well
Filtration
Green-White Sludge
Na_2S
Sulfide
Precipitation
Black Precipitate
Well Coagulated
Filtration
Black Sludge
Colorless Filtrate
To Analysis

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
1.71	0.035	0.02	0.19	0.65	0.045	0.09	8.65

Figure 18. Industry G industries waste characteristics, sample no. 23.

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An investigation at the plant revealed that the entire wastes could be best represented by Samples Nos. 32, 34, and 37. These samples represent wastes from a highly sophisticated operation and are ideal for the type of work for which the bench-scale treatment plant was conceived.

Considerable work was performed to thoroughly investigate these three samples, but the remaining samples were not examined. Flow diagrams of the various analyses conducted are presented in Figures 19, 20, and 21.

The treatment of chromate wastes (Figure 19) showed that if the reduction of chromate ion is carried out to the completion of the reaction, the rest of the metals can be removed by sulfide precipitation, either (a) in the absence of both hydroxide precipitates and an excess of Fe^{2+} (Sequence A), (b) in the absence of hydroxide precipitates but in the presence of Fe^{2+} (Sequence B), and (c) in the presence of both hydroxide precipitates and Fe^{2+} (Sequnce BII).

Treatment of a sample of rinse water collected in a pH neutralization tank (Figure 20) indicated that sulfide precipitation lowers the concentration of all the toxic heavy metals to below 0.1 mg/1, with the exception of nickel and lead. Millipore filtration of Sample No. 37 (Sequence III) followed by sulfide precipitation provided slightly lower concentrations of both metals than the final effluents resulting from a filtration through a Whatman 40 filter (Sequence I), both of which were followed by sulfide precipitation. These analyses indicated the association of nickel and lead with the final dispersed colloids in the system. It was concluded that the proper coagulation of the precipitated sulfides using coagulant aids would definitely reduce the concentrations of these metals in the final effluent.

Tests performed with a sample of waste from the cyanide collection tank (Figure 21) indicated that once cyanides and cyanates are completely oxidized, the metals freed from the cyanide complexes, as well as the other metals, can be very easily precipitated as sulfides and removed from the system. The cyanide oxidation curve is shown in Figure 22.

Industry H--Industry H operates an integrated metals machine shop for the manufacturing of aircraft actuators for hydraulic and other systems. The complete component including electrical motors is manufactured at the plant. The industry operates a plating line and has neutralization ponds which appear to be undersized for peak flow periods. As a pond completely evaporates, the sludge is removed and hauled to a Class I landfill site. Two samples were collected at Industry H and labeled as follows:

No. 24 - Evaporation ponds subsurface
No. 25 - Evaporation pond surface

Each sample was examined and its treating characterisitics were determined as shown in Figures 23 and 14. Both samples were treated for cyanides and chromates. After hydroxide precipitation (Step No. 4 in both figures), Sample No. 24 (Figure 23) was split in two parts in order to test the influence of the presence of precipitated heavy metal hydroxides (including $Cr(OH)_3$ (S) on sulfide precipitation.) As in the previous cases, there was no

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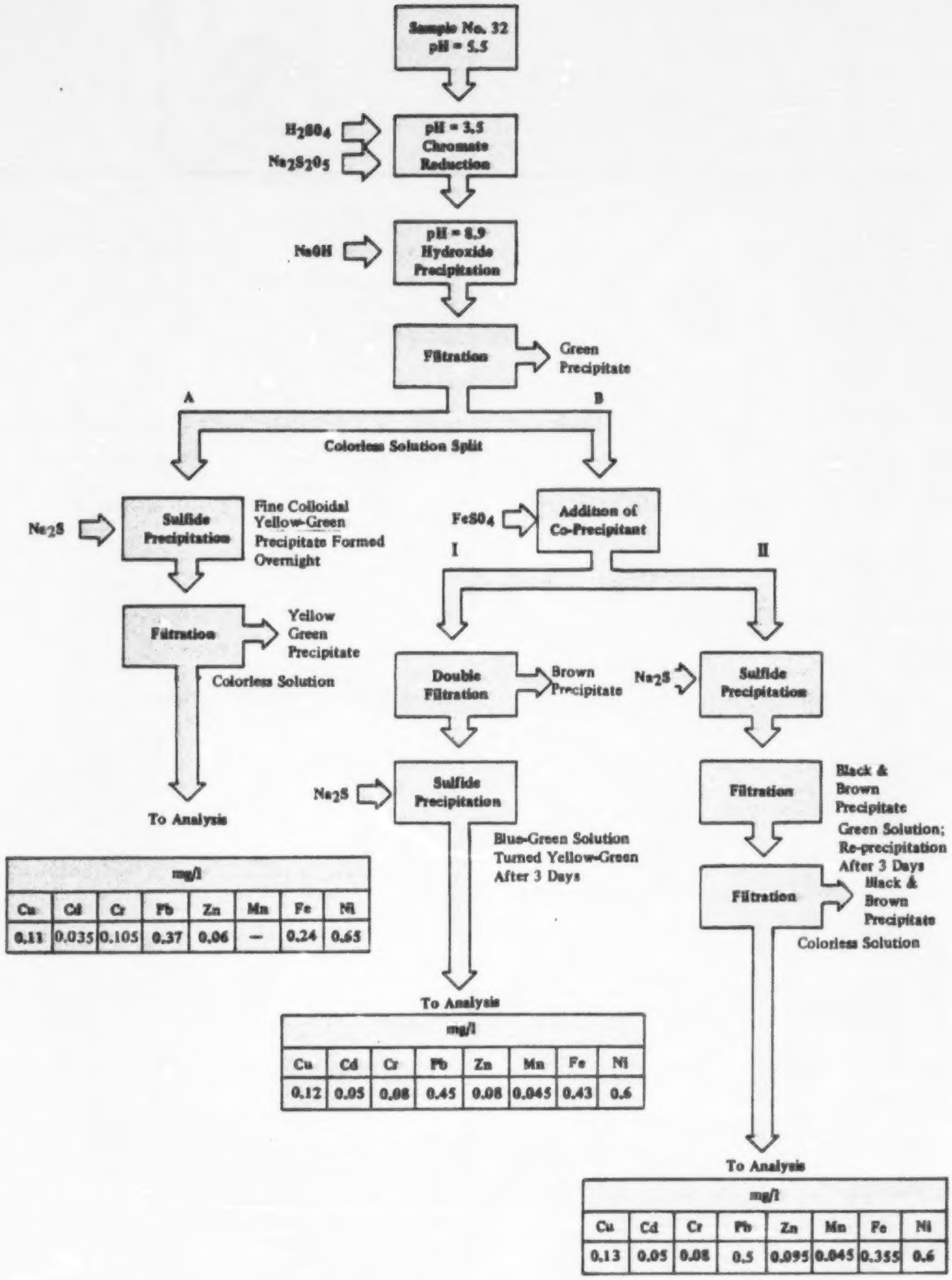
Sample No. 32
pH = 5.5
H_2SO_4
$Na_2S_2O_5$
pH = 3.5
Chromate Reduction
NaOH
pH = 8.9
Hydroxide Precipitation
Filtration
Green Precipitate
A
B
Colorless Solution Split
Na_2S
Sulfide Precipitation
Fine Colloidal Yellow-Green Precipitate Formed Overnight
Filtration
Yellow Green Precipitate
Colorless Solution
To Analysis
$FeSO_4$
Addition of Co-Precipitant
I
II
Double Filtration
Brown Precipitate
Na_2S
Sulfide Precipitation
Na_2S
Sulfide Precipitation
Blue-Green Solution Turned Yellow-Green After 3 Days
To Analysis
Filtration
Black & Brown Precipitate
Green Solution; Re-precipitation After 3 Days
Filtration
Black & Brown Precipitate
Colorless Solution
To Analysis

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.11	0.035	0.105	0.37	0.06	—	0.24	0.65

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.12	0.05	0.08	0.45	0.08	0.045	0.43	0.6

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.13	0.05	0.08	0.5	0.095	0.045	0.355	0.6

Figure 19. Industry I fasteners waste characteristics, sample no. 32.

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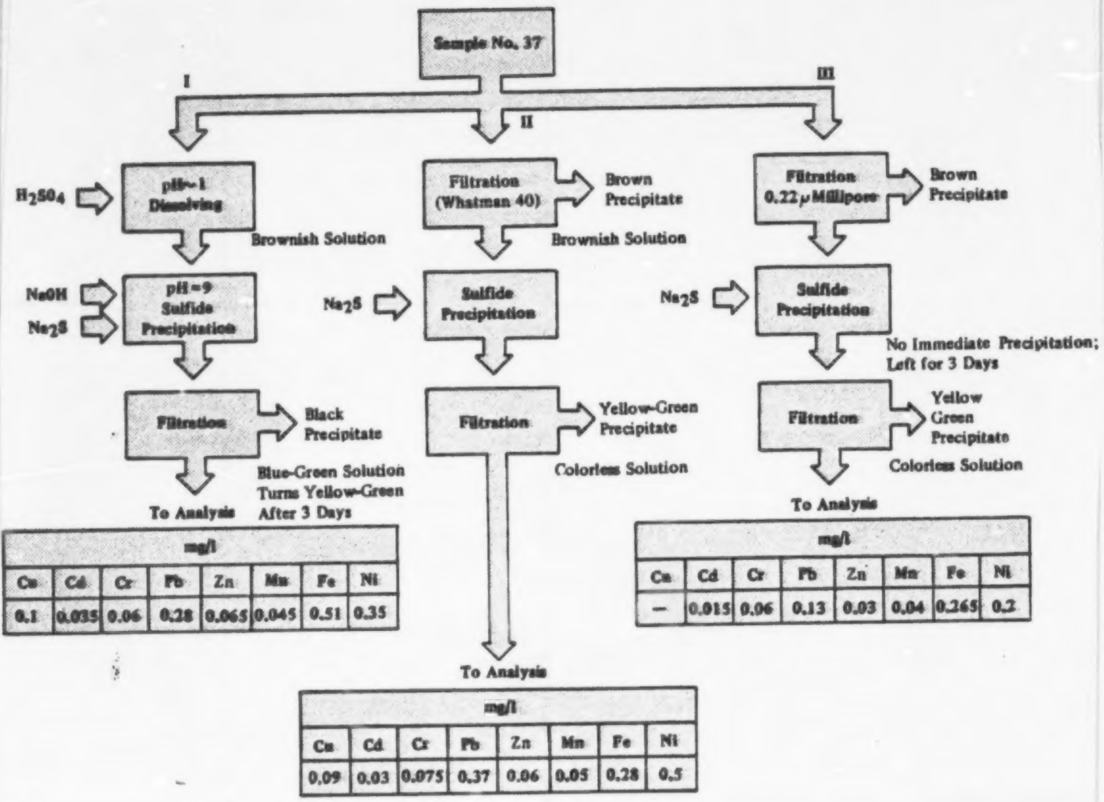
Sample No. 37
I
II
III
H_2SO_4
pH~1 Dissolving
Brownish Solution
NaOH
Na_2S
pH=9 Sulfide Precipitation
Filtration
Black Precipitate
Blue-Green Solution Turns Yellow-Green After 3 Days
To Analysis
Filtration (Whatman 40)
Brown Precipitate
Brownish Solution
Na_2S
Sulfide Precipitation
Filtration
Yellow-Green Precipitate
Colorless Solution
To Analysis
Filtration 0.22 μ Millipore
Brown Precipitate
Na_2S
Sulfide Precipitation
No Immediate Precipitation; Left for 3 Days
Filtration
Yellow Green Precipitate
Colorless Solution
To Analysis

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.1	0.035	0.06	0.28	0.065	0.045	0.51	0.35

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.09	0.03	0.075	0.37	0.06	0.05	0.28	0.5

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
—	0.015	0.06	0.13	0.03	0.04	0.265	0.2

Figure 20. Industry I fasteners waste characteristics, sample no. 37.

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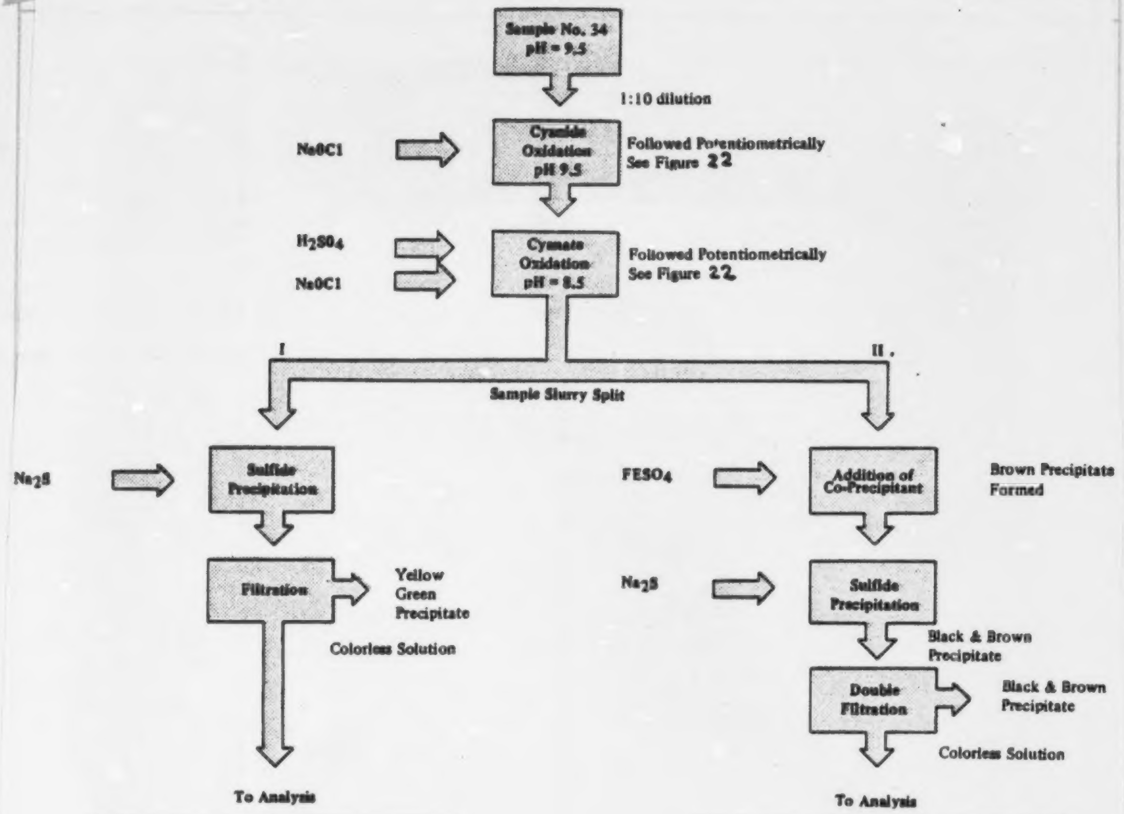
Sample No. 34
pH = 9.5
1:10 dilution
NaOCl
Cyanide Oxidation pH 9.5
Followed Potentiometrically See Figure 22
H_2SO_4
NaOCl
Cyanate Oxidation pH = 8.5
Followed Potentiometrically See Figure 22
I
II.
Sample Slurry Split
Na_2S
Sulfide Precipitation
FESO4
Addition of Co-Precipitant
Brown Precipitate Formed
Filtration
Yellow Green Precipitate
Colorless Solution
Na_2S
Sulfide Precipitation
Black & Brown Precipitate
Double Filtration
Black & Brown Precipitate
Colorless Solution
To Analysis
To Analysis

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.04	0.03	0.01	0.12	0.03	0.03	0.735	0.2

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.06	0.03	0.02	0.16	0.045	0.04	0.745	0.3

Figure 21. Industry I fasteners waste characteristics sample no. 34.

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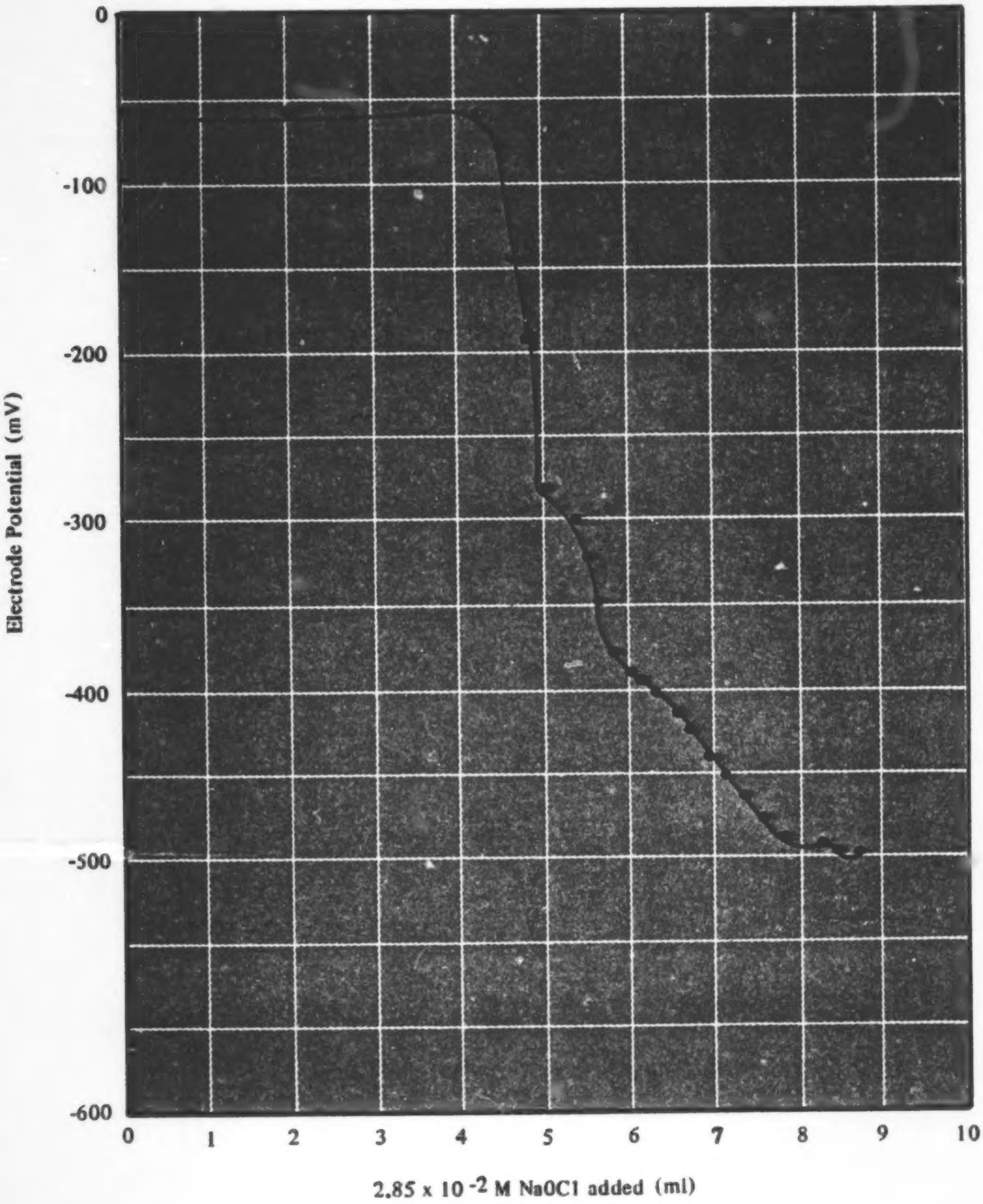

Figure 22. Oxidation of cyanides and cyanates with NaOCl in sample no. 34 from industry 1.

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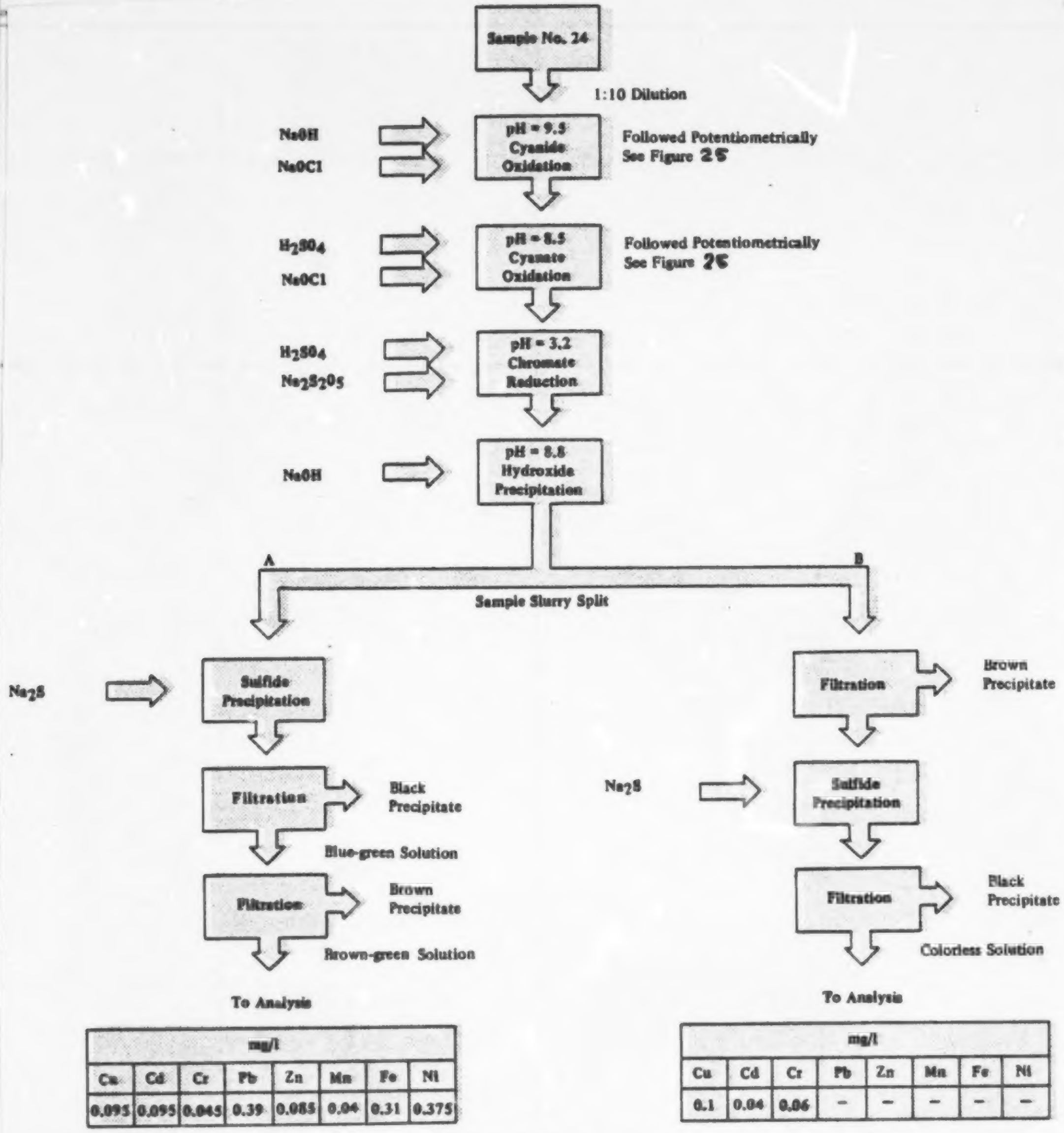
Sample No. 24
1:10 Dilution
NaOH
NaOCl
pH = 9.5 Cyanide Oxidation
Followed Potentiometrically See Figure 25
H_2SO_4
NaOCl
pH = 8.5 Cyanate Oxidation
Followed Potentiometrically See Figure 26
H_2SO_4
$Na_2S_2O_5$
pH = 3.2 Chromate Reduction
NaOH
pH = 8.8 Hydroxide Precipitation
A
B
Sample Slurry Split
Na_2S
Sulfide Precipitation
Filtration
Black Precipitate
Blue-green Solution
Filtration
Brown Precipitate
Brown-green Solution
To Analysis
Filtration
Brown Precipitate
Na_2S
Sulfide Precipitation
Filtration
Black Precipitate
Colorless Solution
To Analysis

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.095	0.095	0.045	0.39	0.085	0.04	0.31	0.375

mg/l							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.1	0.04	0.06	–	–	–	–	–

Figure 23. Industry H corporation waste characteristics, sample no. 24.

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evidence of interferences with sulfide precipitation. Precipitated $Cr(OH)_3(S)$ in Sample No. 25 (Figure 24) was removed by filtration. Sulfide precipitation was carried out in the presence of $Fe(OH)_2(S)$ and an excess of Fe^{2+}. The concentrations of heavy metals in the resulting influent related quite well to the level detected in the final effluents of Sample No. 24 with the exception of zinc. The reasons for higher concentrations of zinc in the final effluent of Sample No. 25 might have been due to the presence of organic matter resulting from biological activity on the surface of the evaporation ponds. If this is the case, it would be necessary to subject this sample to prolonged oxidation with NaOCl in order to break metal-organic liquid complexes. Cyanide destruction curves are shown in Figure 25.

Industry C--Industry C produces high-pressure hydraulic pumps and servovalves for the commercial and military aircraft industry. Considerable machine shop work is involved in the process which uses cutting oils supplied by Mobile Oil Corporation. The industry has no plating line as such, although it does do some specialized electroplating work involving the simultaneous deposition of copper and tin in the bores of certain pressure cylinders used in their equipment. This "bronze plating" is deposited from a cyanide complex. Very little solution and rinse water is used for this process and the process waste is presently treated with calcium hypochlorite to destroy cyanides on-site. The resulting solution and sludges containing both copper and tin are trucked away.

Originally, only one sample was taken, No. 5, which was a cutting oil sump-hydraulic oil. The oil phase of this sample appeared to be a good-quality clear oil which could be separated easily from the aqueous phase. Sample A was ignited in a crucible and it burned evenly without spattering. The residue left upon further heating of the crucible to a dull red heat was insignificantly small and formed a thin oxide film that vaguely discolored the white crucible.

The aqueous phase of Sample No. 5 was treated, as shown in Figure 26, by cyanide oxidation and sulfide precipitation in the presence of $Fe(OH)_2(S)$ and an excess of ferrous ion.. The hydroxide and sulfide precipitates of heavy metals were then coagulated by the addition of a polyelectrolyte. After the removal of flocs by filtration, the filtrate was passed through a carboxylic cation exchange resin and activated carbon column. The analysis of the effluent from the cation exchange step showed very high concentrations of chromium and copper. Concentrations of lead and nickel were much lower than those of chromium and copper but still acceptable. The activated carbon step reduced the levels of all these metals only slightly.

The levels of chromium found in the sample were very high, because chromium reduction had not been carried out. The high levels of copper, nickel, and lead might have been due to traces of undestroyed cyanide and ammonia.

Subsequent to the analysis of Sample No. 5, a sample of the bronze-plating wash was examined. The work done on the analysis of the bronze-plating wash are shown in Figure 27.

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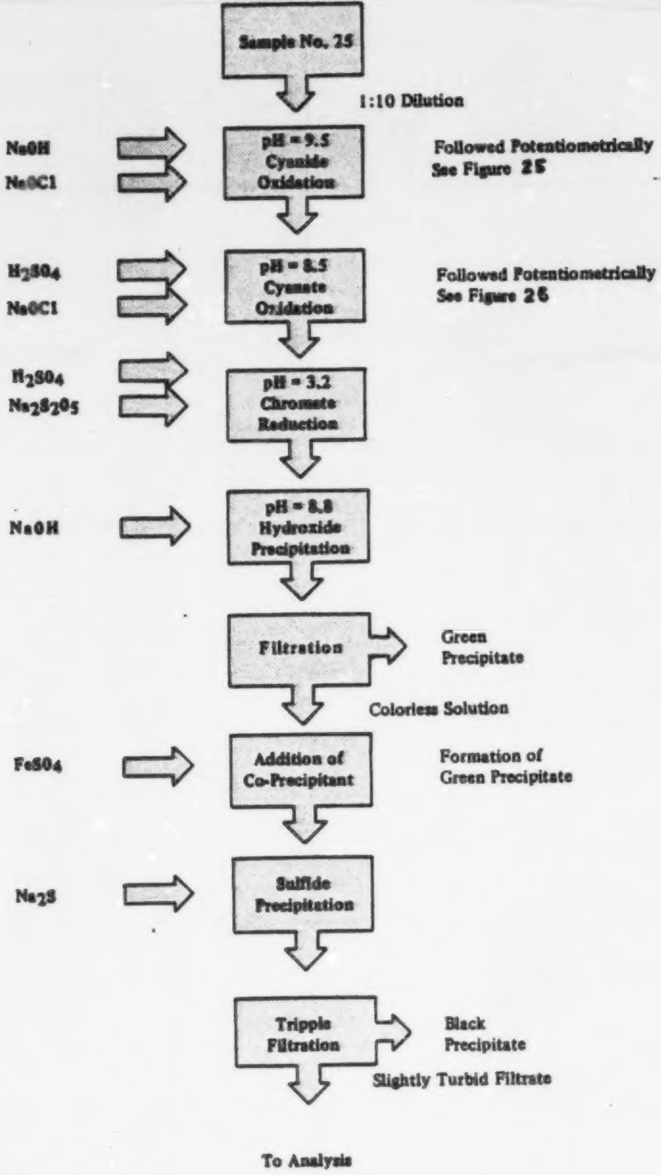
Sample No. 25
1:10 Dilution
NaOH
NaOCl
pH = 9.5
Cyanide
Oxidation
Followed Potentiometrically
See Figure 25
H_2SO_4
NaOCl
pH = 8.5
Cyanate
Oxidation
Followed Potentiometrically
See Figure 26
H_2SO_4
$Na_2S_2O_5$
pH = 3.2
Chromate
Reduction
NaOH
pH = 8.8
Hydroxide
Precipitation
Filtration
Green
Precipitate
Colorless Solution
$FeSO_4$
Addition of
Co-Precipitant
Formation of
Green Precipitate
Na_2S
Sulfide
Precipitation
Tripple
Filtration
Black
Precipitate
Slightly Turbid Filtrate
To Analysis

(mg/l)							
Cu	Cd	Cr	Pb	Zn	Mn	Fe	Ni
0.19	0.1	0.17	0.39	1.56	0.055	1.23	0.375

Figure 24. Industry H corporation waste characteristsics, sample no. 25.

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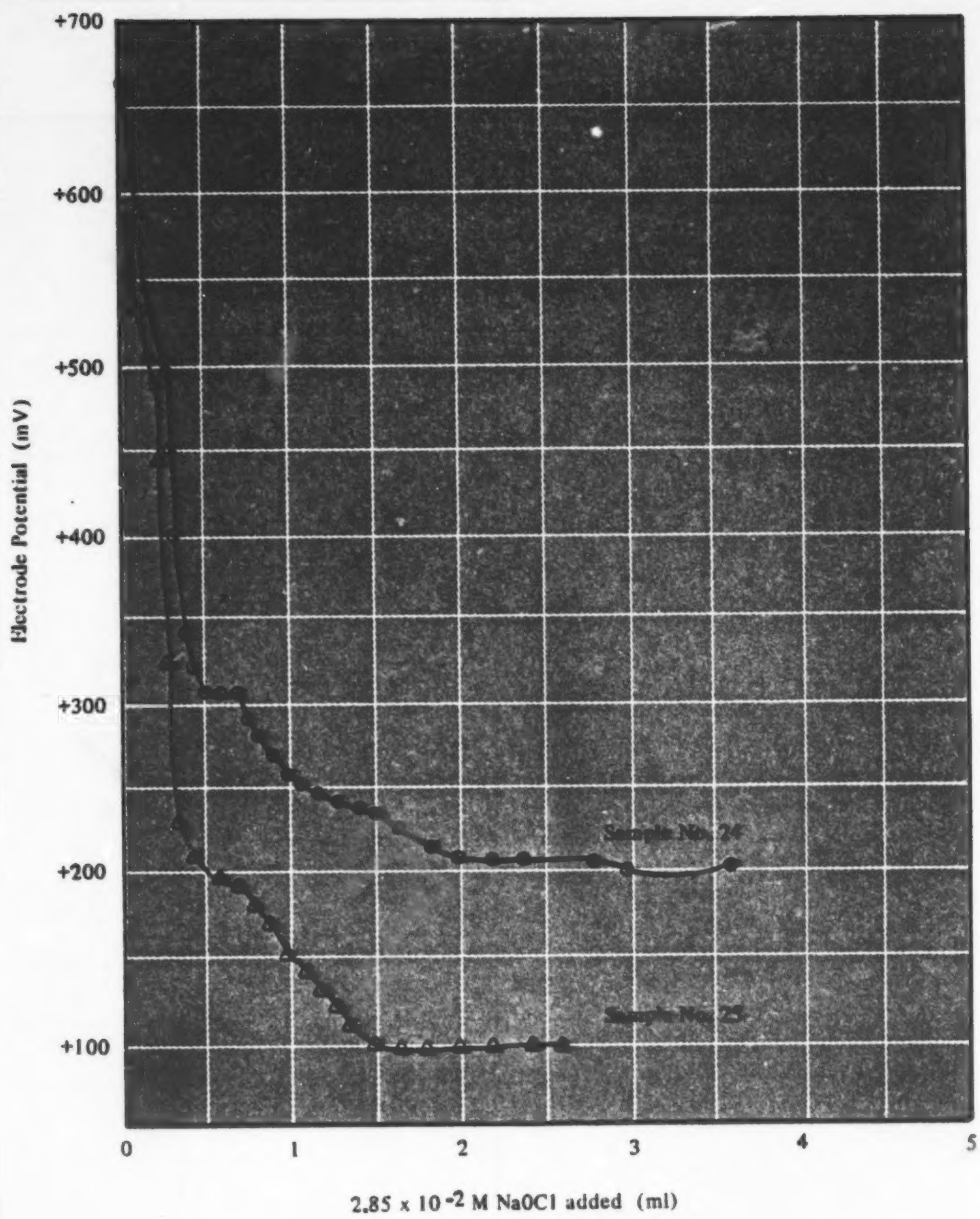

Figure 25. Oxidation of cyanides and cyanates with NaOCl in samples from talley industry H.

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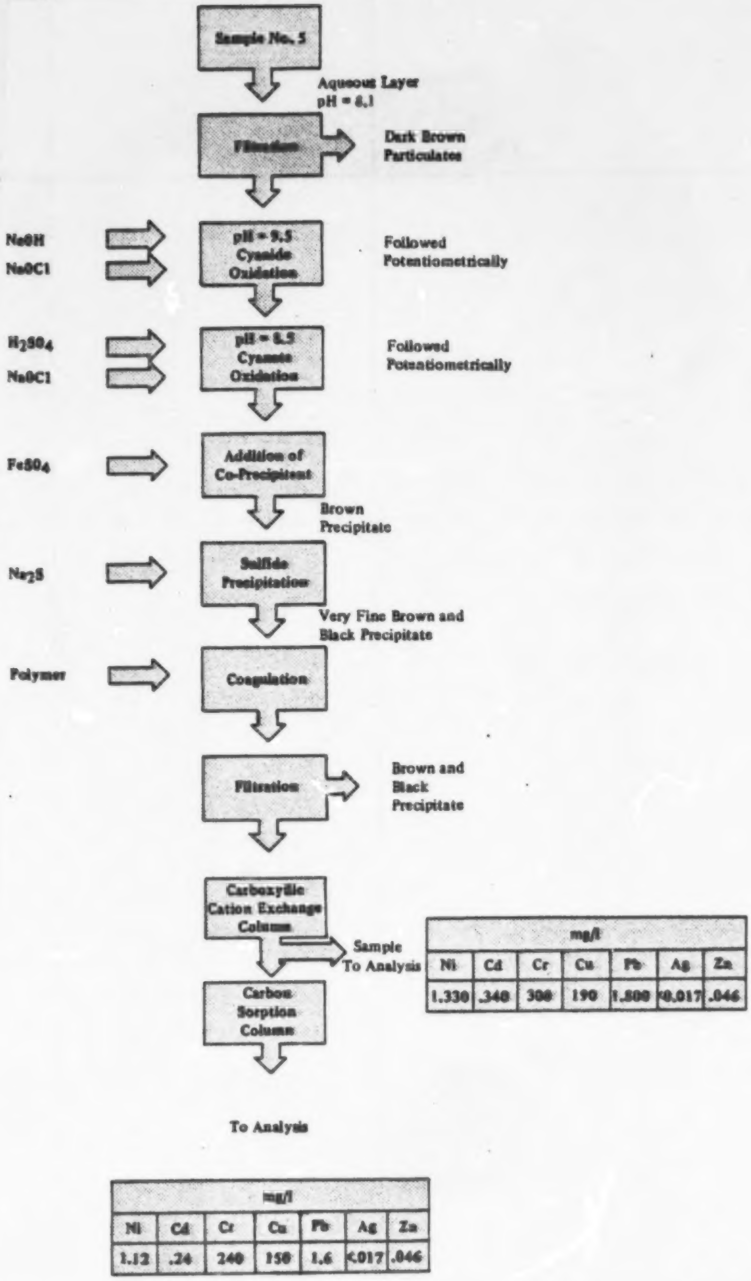
Sample No. 5
Aqueous Layer
pH = 8.1
Filtration
Dark Brown Particulates
NaOH
NaOCl
pH = 9.5
Cyanide Oxidation
Followed Potentiometrically
H_2SO_4
NaOCl
pH = 8.5
Cyanate Oxidation
Followed Potentiometrically
$FeSO_4$
Addition of Co-Precipitant
Brown Precipitate
Na_2S
Sulfide Precipitation
Very Fine Brown and Black Precipitate
Polymer
Coagulation
Filtration
Brown and Black Precipitate
Carboxylic Cation Exchange Column
Sample To Analysis
Carbon Sorption Column
To Analysis

mg/l						
Ni	Cd	Cr	Cu	Pb	Ag	Zn
1.330	.340	300	190	1.800	<0.017	.046

mg/l						
Ni	Cd	Cr	Cu	Pb	Ag	Zn
1.12	.24	240	150	1.6	<.017	.046

Figure 26. Industry C waste characteristics, sample no. 5.

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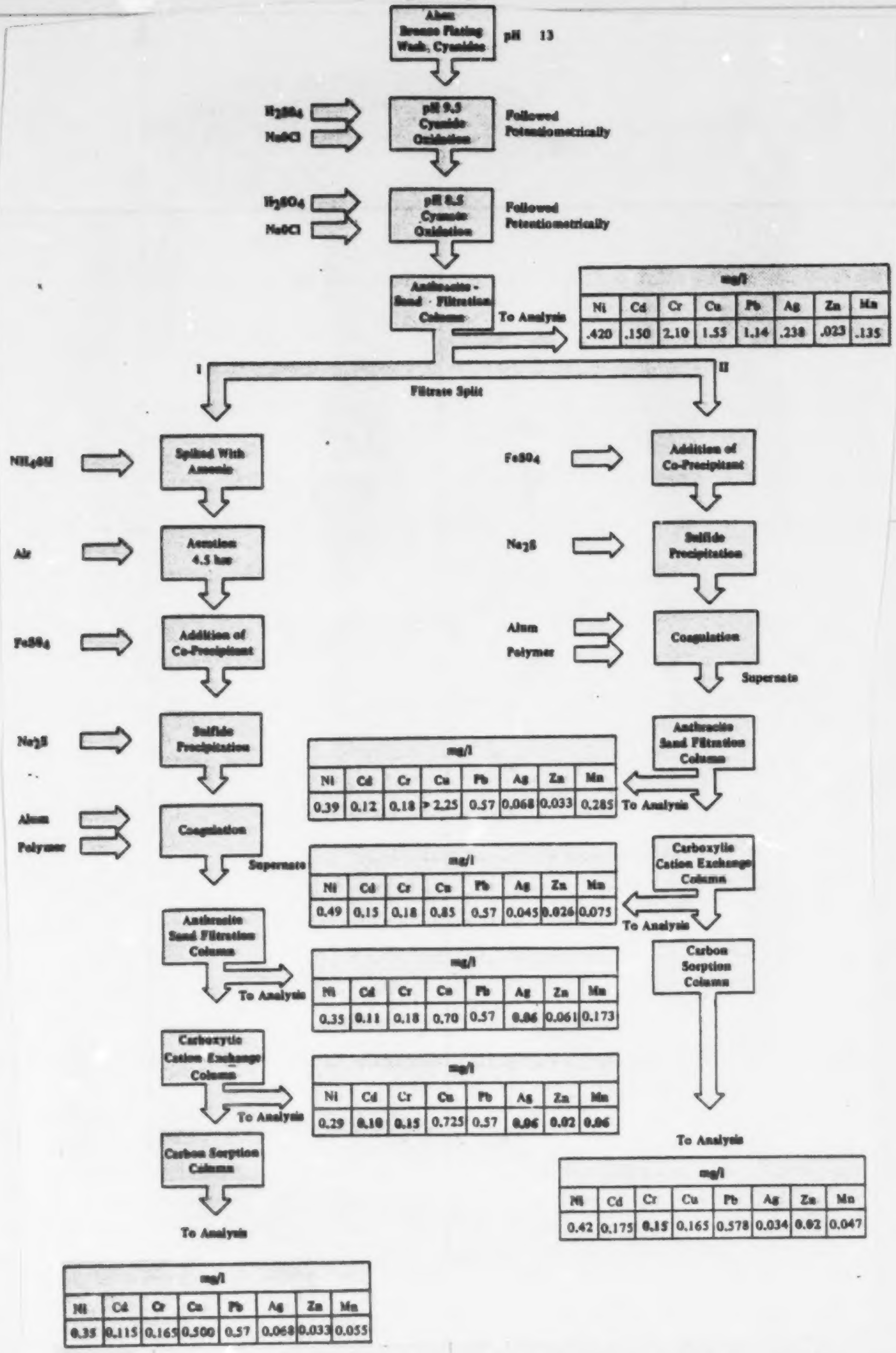
Alum Bronze Plating Wash, Cyanides
pH 13
H$_2$SO$_4$
NaOCl
pH 9.5 Cyanide Oxidation
Followed Potentiometrically
H$_2$SO$_4$
NaOCl
pH 8.5 Cyanate Oxidation
Followed Potentiometrically
Anthracite - Sand - Filtration Column
To Analysis
I
II
Filtrate Split
NH$_4$OH
Spiked With Ammonia
Air
Aeration 4.5 hrs
FeSO$_4$
Addition of Co-Precipitant
Na$_2$S
Sulfide Precipitation
Alum
Polymer
Coagulation
Supernate
Anthracite Sand Filtration Column
To Analysis
Carboxylic Cation Exchange Column
To Analysis
Carbon Sorption Column
To Analysis
FeSO$_4$
Addition of Co-Precipitant
Na$_2$S
Sulfide Precipitation
Alum
Polymer
Coagulation
Supernate
Anthracite Sand Filtration Column
To Analysis
Carboxylic Cation Exchange Column
To Analysis
Carbon Sorption Column
To Analysis

mg/l							
Ni	Cd	Cr	Cu	Pb	Ag	Zn	Mn
.420	.150	2.10	1.55	1.14	.238	.023	.135

mg/l							
Ni	Cd	Cr	Cu	Pb	Ag	Zn	Mn
0.39	0.12	0.18	> 2.25	0.57	0.068	0.033	0.285

mg/l							
Ni	Cd	Cr	Cu	Pb	Ag	Zn	Mn
0.49	0.15	0.18	0.85	0.57	0.045	0.026	0.075

mg/l							
Ni	Cd	Cr	Cu	Pb	Ag	Zn	Mn
0.35	0.11	0.18	0.70	0.57	0.06	0.061	0.173

mg/l							
Ni	Cd	Cr	Cu	Pb	Ag	Zn	Mn
0.29	0.10	0.15	0.725	0.57	0.06	0.02	0.06

mg/l							
Ni	Cd	Cr	Cu	Pb	Ag	Zn	Mn
0.42	0.175	0.15	0.165	0.578	0.034	0.02	0.047

mg/l							
Ni	Cd	Cr	Cu	Pb	Ag	Zn	Mn
0.35	0.115	0.165	0.500	0.57	0.068	0.033	0.055

Figure 27. Industry C waste characteristics bronze plating wash, cyanides.

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It is to be noted that in processing the bronze-plating wash sample, the filtrate from the cyanide destruction and hydroxide filtration was split into two parts. One part (Sequence I) was spiked with ammonia to test the effect of possible residual ammonia after aeration on heavy metal residuals, especially copper.

In both sequences (I and II), the effluents resulting from different treatment steps (i.e., anthracite sand filtration, carboxylic cation exchange, and activated carbon sorption) contained remarkably similar concentrations of all the metals with the exception of copper, whose residual concentration was obviously controlled by the presence of ammonia. Comparison of the analysis of the final effluents from both sequences with the effluent from the dual-media filtration following cyanide and cyanate oxidation showed very little removal of nickel, cadmium, and zinc by sulfide precipitation. The reason for these low metal removal levels, especially in the case of nickel, might have been the presence of undestroyed cyanide complexes.

Industry B--Industry B is a very large supplier and distributor of a full line of agricultural chemicals and supplies. The industry not only sells the products but also applies them in the field. The chemicals are blended, diluted, and located at the company's premises, and the equipment is returned for washing, draining, and flushing to the same premises. The industry handles much of its ingredients in bulk. The industries primary waste disposal problem is precipitated solids (wettable powders, etc.), and greases and oil (which are used in preparing pesticide emulsions). The wastes from mixing, etc., go to a sump where some materials settle, others float, and still others are held in solution. Wastes from a sump are pumped and hauled away to a Class I landfill. These wastes include approximately 3,000 gallons of dilute washings produced each month from cleaning the outside of the equipment. The company also operates an airborne pesticide application service, and the cleaning operation for the equipment needed in this operation is performed at the airport. Two samples were taken at Industry B:

No. 3 - Washout grease oil sump, pesticide and fertilizer, subsurface sample

No. 4 - Washout grease oil sump, pesticide and fertilizer, surface sample

Sample No. 4 was centrifuged at approximately 4,000 rpm for 30 minutes. Six distinct layers resulted from the centrifugation: (1) small sediment layer, mostly sand, (2) a clear aqueous solution, (3) an oil-in-water emulsion, (4) a water-in-oil emulsion, (5) an oil layer, and (6) an emulsion layer that contained very fine particulate matter,

Attempts to coagulate Sample No. 4 were unsuccessful when a medium molecular weight cationic polyelectrolyte was used. When the sample was heated in a crucible to a high temperature, it ignited after the water evaporated and burned with a smoky flame, leaving only a film of residue and a few grains of sand. None of the treatment methods visualized for this study are believed to be operable in regards to this waste and none would be competitive with using the waste as a low-grade fuel source; consequently, no work was done on this sample. This illustrates the fact that segregating various wastes from some establishments will be mandatory and cost effective, rather than treating the mix at a regional residual waste facility.

Sample No. 3 was foamed in the foam fractionation-flotation device, but the experiment was short-lived because the off-gas was nauseating. Consequently, it was decided that quantitative work and foam fractionation on toxic, nonmetallic waste will be done if possible on Industry E's sample, which is discussed in the next section. Samples from Industry F, which contain organic components, also offers opportunities for evaluation of the foam fractionation-flotation device.

Industry E--Industry E sells fertilizers and pesticides for row crops and provides an application service. Oil emulsions are apparently not required for row crops. All the chemicals used by this industry are diluted and/or blended at the site of application, and the containers are triple-rinsed with water also at the site. All the chemicals thus can be used at the agricultural site. The equipment is, however, washed at the plant. This wash is collected in a sump at the average rate of a few hundred gallons per month and is hauled away to a Class I landfill. Some fertilizers as well as insecticides get into the sump. Mixing and blending at the agricultural site where the pesticide or fertilizer is applied, would seem to be the most logical method for any purveyor to reduce the level of toxic materials which must be disposed of. The two samples that were collected at the plant were:

No. 17 - Surface of pesticide and fertilizer sump for washouts

No. 18 - Substance of pesticide and fertilizer sump for washouts

Sample No. 17 was an almost colorless liquid that contained essentially no sediment. Sample No. 18 contained considerable finely divided sediment. After some preliminary work with both samples, a larger sample (resample of No. 17) was collected for use in a series of operations for treating nonmetallic wastes. Turbidity and color were visible in this sample. This was due to a fine sediment which contained organics. The levels of organic carbon and turbidity in the waste were lowered very significantly by each of three different treatment process sequences described in the subsequent section on treatment of various residual wastes. Determination of waste characteristics and the treatment of the various wastes found in this sample were considered to be coincide; consequently, in the discussion of the treatment of the various residual wastes, their characteristics will also be presented.

Industry F--Industry F manufactures Fiberglas reinforced plastic bathtubs and shower stalls. They make their own dies and polyester. The glass fiber and chemicals are delivered to the plant from outside manufacturers. A sump is maintained on-site, which accumulates resin dust, styrene vapors, catalyst vapors, etc., in a water solution which is occasionally pumped out and hauled away. Acetone is used as a solvent for washing tools, and solutions of this wash are collected and hauled away by a solvent reclaimer for recovery of acetone that has not evaporated. The industry does not cook the polyester on site; however, the styrene monomer, methylethyl ketone peroxide, and other toxic ingredients are added to the polyester mix at the site.

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The glass used in manufacturing is pretreated elsewhere in such a manner that the glass and polyester form a chemical bond. A polyurethane layer, formed in place from diisocyanates and a polyglycol, is also used in what is termed laying up the pieces. Methylene chloride is used as a solvent for the polyester resin as it is laid up. Cobalt oxalate, acetyl acetone, "cobalt octolate," and other hazardous or toxic substances are used as catalysts and promotors in the polyester reaction. Aniline and dimethylanilines are used in the polyurethane formulation. Aside from the sump and the acetone recovery previously mentioned, all chemicals end up either in the product as polymers, in the air during heat curing and room temperature curing, or during temperature evaporation of the methylene chloride. Water pollution is minimized, since nearly everything that does not evaporate reacts to form an insoluble solid. It should be pointed out that in addition the sump can contain a variety of toxic substances, which can be quite volatile. Three samples were taken, two of which were labeled identically:

No. 20 - Sump for plant and spray booths

No. 21 - Sump for plant and spray booths

No. 19 - Cooling tower water containing algicide

Since Sample No. 19 represents a material whose examination is beyond the scope of the present study, it was excluded from further study. The algicide was a proprietary product, and information about its composition and behavior in cooling towers could be obtained from the vendor of the product.

The sump material was studied in some detail as a good example of a nonmetallic toxic waste. A large sample was obtained from the sump, and total organic carbon determinations and chromotographic analysis were conducted on the sample. These analyses demonstrated the presence of organic compounds. The chromotographic analysis indicated a large variety of components. This sample was also turbid. The flow diagram of the treatment process and the results for this sample are described in the next section covering treatment of various residual wastes.

Treatment of Various Residual Wastes--

Treatment of residual wastes, as opposed to characterization discussed in the preceding section is defined as subjecting wastes to physical-chemical conditions and processes planned to improve the quality of the waste to a level that it can be disposed of by a designated means. On the basis of the waste characteristics, the target for level of treatment that appears to be realistic for Ventura County, considering the nature and volume of wastes, is the limits set forth in the industrial waste discharge ordinance for the City of Oxnard sewerage system.

The objective of the work reported in this section is to identify a comprehensive liquid waste treatment system for the residual wastes to achieve discharge quality compliance. Treatment of the solids fraction of residual wastes is reported in the following section.

The work of this section supplements that of the preceding section, Waste Characteristics. The purpose of these treatability studies is to achieve the following:

1. To arrive at adequate general methods for treating toxic metallic wastes, to allow mixtures of appropriate samples from VRCSD to be treated satisfactorily. These methods would be flexible enough to accomodate the ever-changing composition of wastes anticipated at the proposed plant.

2. To determine an optimum cost-effective process for treating nonmetallic toxic wastes, oily wastes, and brine wastes originating within the boundaries of VRCSD. This would include defining appropriate unit operations such as foam fractionation-flotation, carbon sorption, etc.

To identify the best overall treatment process scheme, mixtures of all of the metallic toxic wastes which are more difficult to treat were applied to the best general treatment process surmised from the results of the treatability for each of those wastes reported in the previous section. This section also includes the results of the investigation on the effectiveness of various processes in removing nonmetallic toxic substances.

By forming a composite mixture of the heavy metal wastes sampled, a certain degree of complexing not encountered in component samples was achieved. This was done on purpose so as to generate a waste stream that would be as complicated and difficult to treat as any likely to be found in Ventura County. It was reasoned that if the processes proposed for the prototype plant could effectively remove metals to acceptable levels, the plant could also be expected to remove metals in the residual waste streams trucked to the facility to acceptable levels.

Treatment effectiveness--The samples of toxic metallic wastes used to prepare the two composites are listed in Table 7. These samples were grouped into two categories: cyanide wastes and noncyanide wastes. The two samples selected for the nonmetallic toxic waste treatment are also indicated in Table 7:

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TABLE 7. SAMPLES EXAMINED IN DETERMINING EFFECTIVENESS OF VARIOUS TREATMENT PROCESSES

Composite Sample No.	Composition Samples
	Cyanide Wastes:
Metallic Waste No. 1	No. 6 9 10 11 12 15 22 23 24 25 34
	Non-Cyanide Wastes:
Metallic Waste No. 2	No. 7 8 13 14 16 32 37
Non-Metallic Toxic Waste No. 1	No. 17
Non-Metallic Toxic Waste No. 2	Resample of No. 20

1. Metallic waste

The first treatment sequences were carried out on a 1:10 dilution of toxic metallic wastes as indicated on Figure 28. A 1:10 dilution was used preliminarily in the interest of discovering potential problems rapidly.

The first of three alternative sequences studied included the steps indicated under Sequence I in Figure 28. The cyanide-destruction titration curve for this composite is shown in Figure 29. The precipitation of metals in the form of their respective sulfides in the absence of an excess of iron results in higher than expected residual concentrations of all the metals. The concentration of nickel was particularly high.

When an excess of sulfide iron is employed in a sulfide precipitation, some metals may form anions containing sulfur that are soluble in strongly basic solutions, e.g., $NiS + S^{=} = NiS_2^{=}$. If the sulfide precipitation is carried out in the presence of an excess of Fe^{2+} (Sequences IIA and B), the Fe^{2+} in the solution might prevent reaction of the excess sulfides with the

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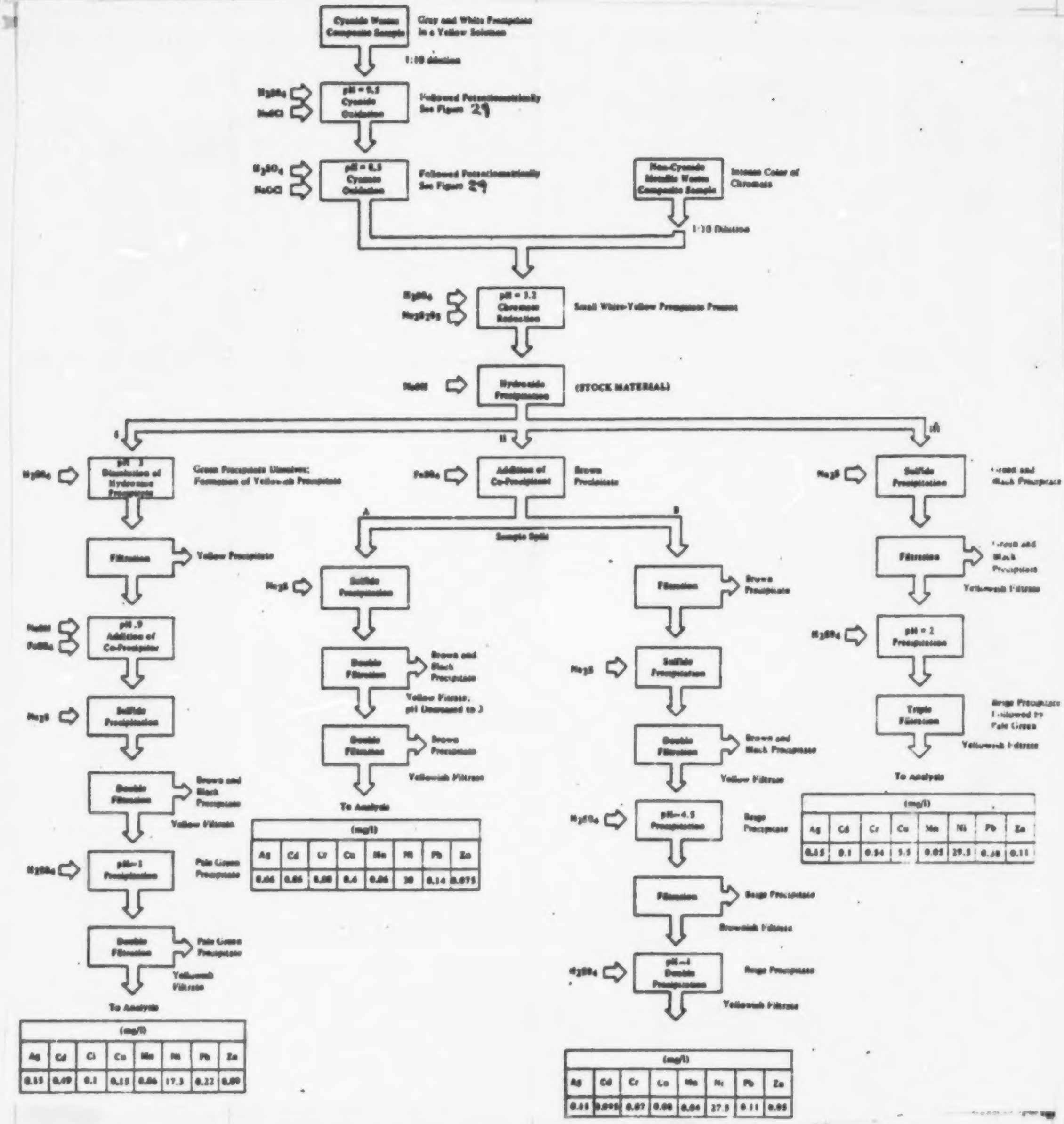
Cyanide Wastes Composite Sample
Gray and White Precipitate in a Yellow Solution
1:10 dilution
H_2SO_4
NaOCl
Cyanide Oxidation
Followed Potentiometrically See Figure 29
Non-Cyanide Metallic Wastes Composite Sample
Intense Color of Chromate
1:10 Dilution
Chromate Reduction
Small White-Yellow Precipitate Present
NaOH
Hydroxide Precipitation
(STOCK MATERIAL)
I
II
III
Dissolution of Hydroxide Precipitate
Green Precipitate Dissolves; Formation of Yellowish Precipitate
$FeSO_4$
Addition of Co-Precipitant
Brown Precipitate
Na_2S
Sulfide Precipitation
Green and Black Precipitate
A
B
Sample Split
Filtration
Yellow Precipitate
Brown Precipitate
Green and Black Precipitate
Yellowish Filtrate
Addition of Co-Precipitant
Double Filtration
Brown and Black Precipitate
Yellow Filtrate, pH Decreased to 3
Brown Precipitate
Yellowish Filtrate
Yellow Filtrate
Pale Green Precipitate
Beige Precipitate
Beige Precipitate Followed by Pale Green
Triple Filtration
Brownish Filtrate
Double Precipitation
To Analysis
(mg/l)
Ag Cd Cr Cu Mn Ni Pb Zn
0.15 0.09 0.1 0.15 0.06 17.3 0.22 0.09
0.06 0.06 0.06 0.4 0.06 30 0.14 0.075
0.65 0.095 0.07 0.06 0.04 27.5 0.11 0.05
0.15 0.1 0.54 5.5 0.05 29.5 0.16 0.11

Figure 28. Treatment of residual wastes: composite of metallic wastes.

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other metals to form polysulfides. Since the hydroxides of most metals, including nickel but excluding cadmium, are quite soluble, it was believed that if polysulfides formation was the problem, it might be beneficial to filter off the hydroxide precipitates before the addition of sulfies (Sequence IIB), rather than to carry out the sulfide precipitation in the presence of hydroxide precipitates (Sequence IIA). Sequences IIA and IIB were carried out simultaneously for cooperative purposes. The analyses of the final filtrates of these sequences showed very small differences in concentrations of eight trace metals (i.e., Ag, Cd, Cr, Cu, Mg, Ni, Pb, Zn), as shown in Figure 28.

It was observed during the chromate reduction step that a small white-yellow precipitate persisted even at pH 3.2. It was though that this material might have caused high residual concentrations of some metals in the final effluent in Sequences I, IIA, and IIB. Consequently, the stock material prepared by hydroxide precipitation at pH 9 after cyanide destruction and chromate reduction was redissolved with H_2SO_4 (see Sequence III) and the precipitate filtered off. The Na_2S precipitation then followed after adding an excess of $FeSO_4$. The results, though better for nickel, were still unsatisfactory, and the cadmium was worse than in the two previous sequences.

Subsequent work on the treatability of the composites of metallic wastes was performed with nondiluted samples. The work carried out as depicted in Figure 30 was predicated on the assumption that the stock material should be the solution resulting from the chromate reduction rather than the resulting one step later in the sequence (pH 9, compare Figure 28 and Figure 30). Thus, Sequences I and II of Figure 30 were carried out beginning with the stock material after reduction of chromate with $Na_2S_2O_5$. Additionally, in the cyanide destruction steps of Figure 30, the reaction times were increased to 8 hours (from 3 hours in previous work) because of documented evidence that nickel cyanides are more difficult to oxidize than some other cyanides. Sequence II, which involved removal of hydroxide precipitates prior to sulfide precipitation, produced a final filtrate that contained a high nickel concentration. Sequence I, involving sulfide precipitation carried out in the presence of hydroxide precipitatates, produced much better results.

Since prolonged oxidation of cyanides and cyanates and precipitation of metal sulfides in the presence of an excess of iron and in the presence of precipitated metal hydroxides proved to be the most effective combination of conditions for the removal of toxic metals from the composite sample (see Figure 30), the sequence of treatments shown in Figure 31 was carried out under these conditions. In addition, the precipitate obtained was then coagulated (for details, see following section on sludge dewatering/thickening) and the supernate passed through the anthracite-sand filtration column. Subsequent treatments involved carboxylic cation exchange and carbon sorption. Samples were taken at three stages of this sequence. At every stage that was sampled and analyzed the results improved and were better than those obtained in any of the sequences depicted in the two previous figures on the composite samples.

On the basis of the experimental results presented in Figure 28, 30, and 31, it can be concluded that the following steps are required for the best probability of a completely successful treatment of cyanide and noncyanide

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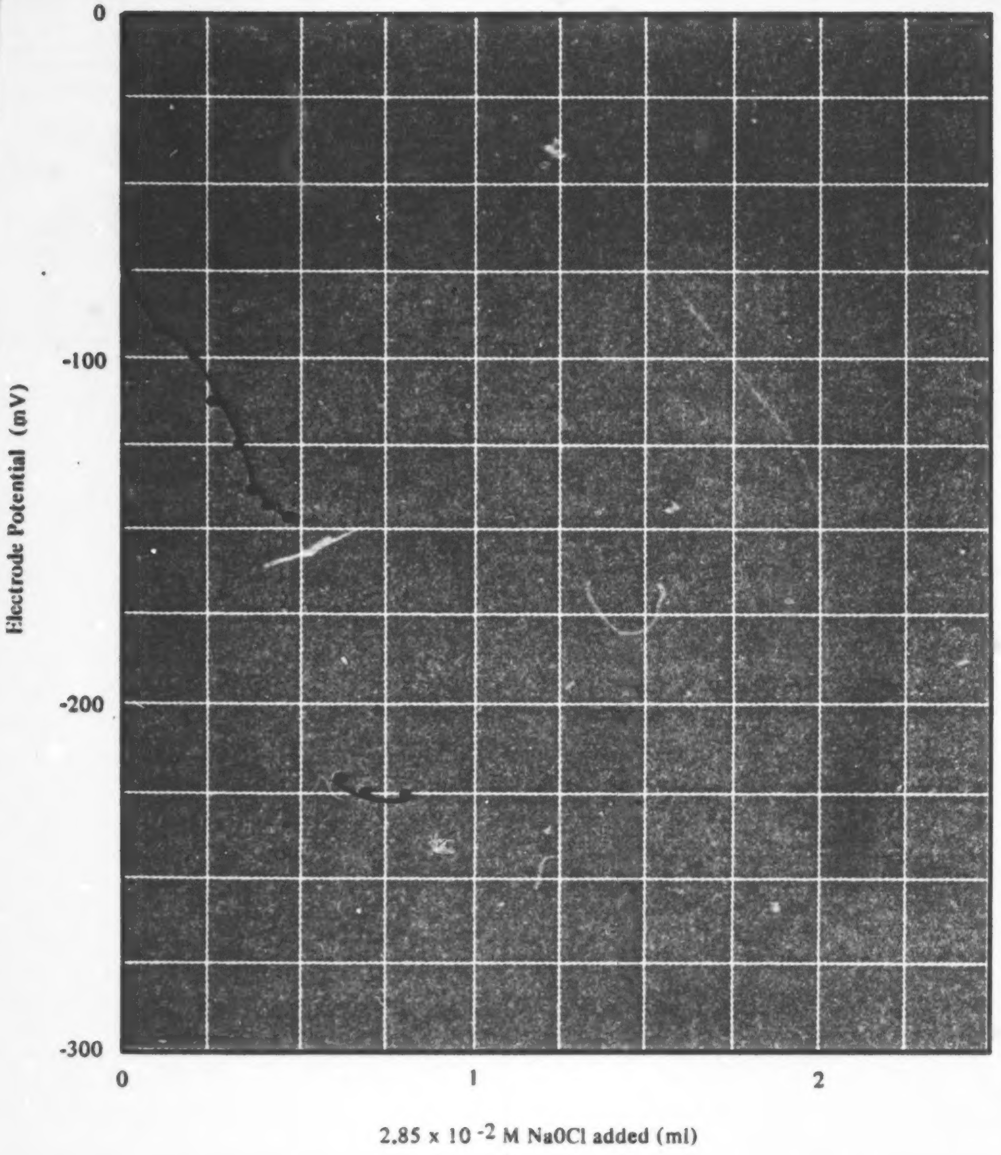

Figure 29. Oxidation of cyanides and cyanates in the composite sample of metallic wastes.

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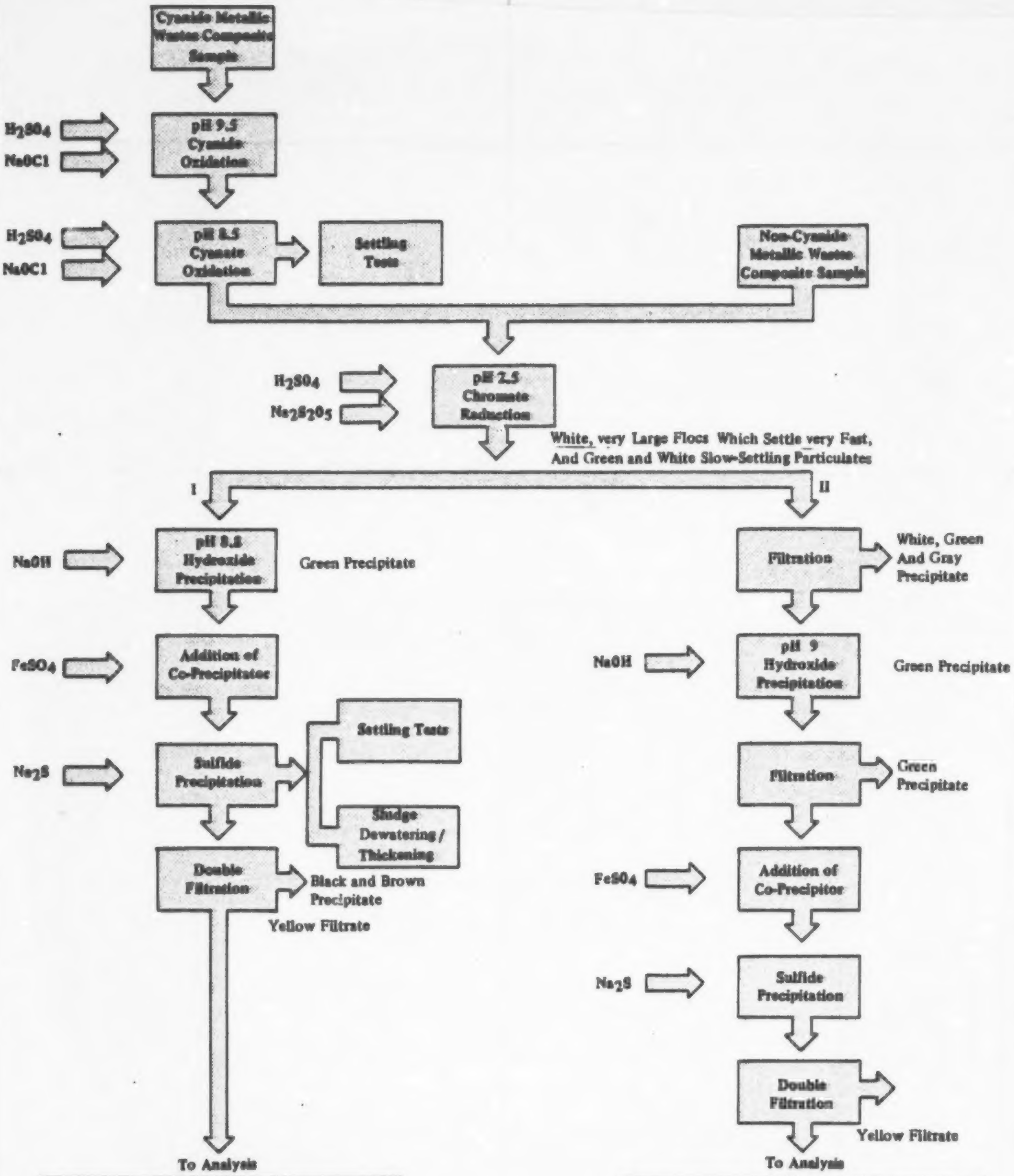
Cyanide Metallic Wastes Composite Sample
H2SO4
NaOCl
pH 9.5 Cyanide Oxidation
H2SO4
NaOCl
pH 8.5 Cyanate Oxidation
Settling Tests
Non-Cyanide Metallic Wastes Composite Sample
H2SO4
Na2S2O5
pH 2.5 Chromate Reduction
White, very Large Flocs Which Settle very Fast, And Green and White Slow-Settling Particulates
I
II
NaOH
pH 8.2 Hydroxide Precipitation
Green Precipitate
FeSO4
Addition of Co-Precipitator
Na2S
Sulfide Precipitation
Settling Tests
Sludge Dewatering / Thickening
Double Filtration
Black and Brown Precipitate
Yellow Filtrate
To Analysis
Filtration
White, Green And Gray Precipitate
NaOH
pH 9 Hydroxide Precipitation
Green Precipitate
Filtration
Green Precipitate
FeSO4
Addition of Co-Precipitor
Na2S
Sulfide Precipitation
Double Filtration
Yellow Filtrate
To Analysis

mg/l							
Ag	Cd	Cr	Cu	Mn	Ni	Pb	Zn
0.06	0.2	0.27	0.2	0.15	0.89	1.0	0.22

mg/l							
Ag	Cd	Cr	Cu	Mn	Ni	Pb	Zn
0.35	0.35	~ 35	0.24	0.59	39.1	0.54	0.5

Figure 30. Treatment of residual wastes composite of metallic wastes.

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metallic wastes:

a. Adjust the pH in both the cyanide and noncyanide metallic wastes to 9.5 separately.

b. Mix the two wastes by transferring the cyanide metallic wastes to the tank that contains the noncyanide metallic wastes.

c. Treat the mixture of wastes with chlorine incrementally, at a constant pH of 9.5, adjusting pH as necessary, to oxidize cyanides to cyanates, and afterwards at a pH of 8.5 to oxidize cyanates to carbon dioxide. This should be followed potentiometrically with due regard for the slowness of the reaction at a pH of 9.5.

d. Lower the pH of the suspension to 4.0 and reduce hexavalent chromium to the chromic state using SO_2.

e. Precipitate the heavy metal ions by raising the pH of the system to a pH of 9.

f. Add ferrous sulfate in five fold excess of the total concentration of relevant heavy metals still remaining in the solution, as determined by an atomic absorption analysis and add H_2S in three fold excess of that necessary to precipitate those relevant heavy metals.

g. Add a polyelectrolyte and flocculate the suspension untial a well-formed, rapidly settling floc is obtained.

h. Allow the precipitate to settle. Decant the bulk of the supernate and filter it through a dual-media filter. This may be followed by a carbon sorption column and a carboxylic ion exchange column in series, as required, depending upon the TOC, the residual heavy metals, and the effluent requirements. In reality, the ion exchange step will most likely not be required. The carbon sorption will not be required unless the limits are imposed on specific organic contaminatns that may enter a sewage treatment plant.

i. Pump substantially all of the sludge to the sludge concentration tank and prepare the tank to receive more untreated noncyanide toxic metallic wastes. After transfer of the treated cyanide toxic metallic wastes to the noncyanide toxic metallic waste tank (Step 2 above), the cyanide toxic metallic wastes tank is ready to receive more raw cyanide wastes.

2. Nonmetallic toxic waste

Sample No. 20 was diluted 1:1 and coagulated with alum (145 mg/l) and three different doses of the medium-high cationic Hercofloc polymer: 0.1 mg/l, 1 mg/l, and 5 mg/l (see Figure 32). Coagulation with a polymer dose of 1 mg/l produced little change in the volatile organic carbon (VOC) or residual organic carbon (ROC) contents of the samples as measured when examining Millipore filtrates from the refiltration time measurements. Coagulation with 5 mg/l of polymer, however, added appreciable ROC as expected. Anthracite-sand filtration of the previously unfiltered supernate resulting from the coagulation

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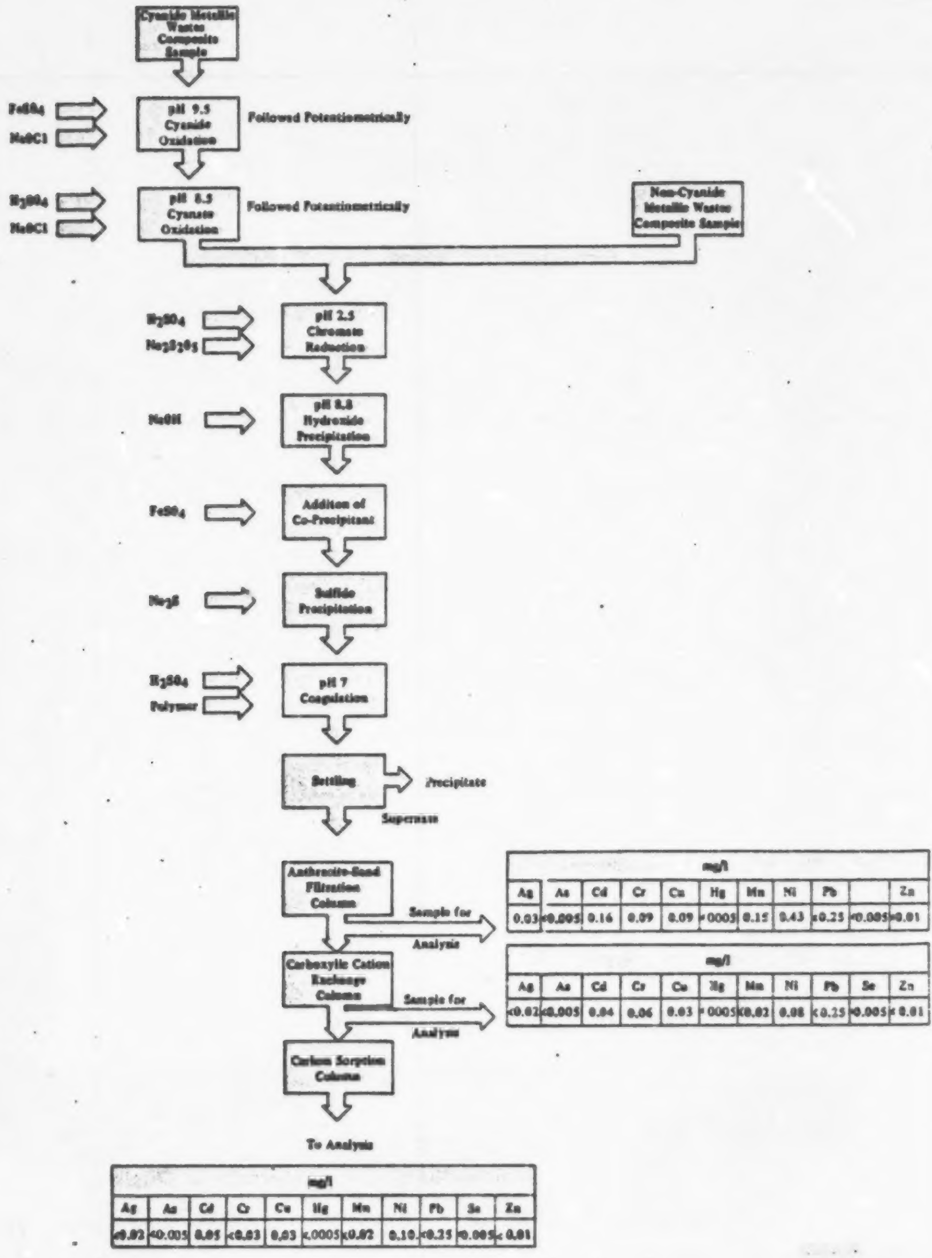
Cyanide Metallic Wastes Composite Sample
$FeSO_4$
NaOCl
pH 9.5 Cyanide Oxidation
Followed Potentiometrically
H_2SO_4
NaOCl
pH 8.5 Cyanate Oxidation
Followed Potentiometrically
Non-Cyanide Metallic Wastes Composite Sample
H_2SO_4
$Na_2S_2O_5$
pH 2.5 Chromate Reduction
NaOH
pH 8.8 Hydroxide Precipitation
$FeSO_4$
Additon of Co-Precipitant
Na_2S
Sulfide Precipitation
H_2SO_4
Polymer
pH 7 Coagulation
Settling
Precipitate
Supernate
Anthracite-Sand Filtration Column
Sample for Analysis
Carboxylic Cation Exchange Column
Sample for Analysis
Carbon Sorption Column
To Analysis

mg/l										
Ag	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb		Zn
0.03	<0.005	0.16	0.09	0.09	<0005	0.15	0.43	<0.25	<0.005	<0.01

mg/l										
Ag	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Se	Zn
<0.02	<0.005	0.04	0.06	0.03	<0005	<0.02	0.08	<0.25	<0.005	< 0.01

mg/l										
Ag	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Se	Zn
<0.02	<0.005	0.05	<0.03	0.03	<.0005	<0.02	0.10	<0.25	<0.005	< 0.01

Figure 31. Treatment of Residual wastes: composite of metallic wastes.

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with a polymer dose of 1 mg/l (the best dose examined) removed a significant portion of the organics as reflected in the total organic carbon (TOC) data, shown also in Figure 32.

Continuing with the treatment indicated in Figure 32, analyses of fractions of the collapsed foam (numbered 1, 2, and 3) resulting from the foaming of the anthracite-sand filtrate during one small addition of detergent (Maprofix SP) to the filtrate in the foam fractionation device showed little change in the concentrations of VOC, while ROC was increased. The detergent was also concentrating in the foam. Indeed, its concentration accounted for a substantial part of the total increase in ROC in the foam.

The residual liquids remaining in the foam fractionation column showed only slightly lower VOC on the average. Large removals of ROC were also not apparent. The decrease in VOC might have been attributed to the removal of volatile organics by the rapid air flow through the column.

In the final treatment step, sorption on activated carbon, both VOC and ROC were lowered dramatically. Approximately 80 percent of the VOC and 90 percent of the ROC remaining in the feed to the sorption column were removed at this step. The turbidity at this point (0.8 JTU) was less than one-fifth of that of diluted Sample No. (4.5 JTU).

Chromatographic analysis, when comparing the 1:1 dilution of Sample 20 and the final carbon sorbed effluent, showed a dramatic reduction in the concentration of some compounds and complete removal of others. In Table 8, the occurrence of peaks at 0.68 and 1.88 minutes retention time in the extracted sample which do not appear in the treated sample, are significant. These peaks were up to 400 times larger than any peak found in the treated sample. Also, the peaks of 3.11 and 5.26 minutes retention time have been reduced by a factor of about 100. In addition, the solvent peak for hexane at 0.37 minutes showed that the treated sample injection was approximately 17 percent larger than the raw sample injection. Therefore, due to syringe techniques (which are not highly reproducible at the microliter level), the percentages of removals were even greater than those indicated in Table 8.

Sample No. 17 was treated by employing three different treatment sequences as shown in Figure 33. The first sequence (II in Figure 33) involved simple anthracite-sand filtration of the undiluted sample followed by sorption on activated carbon. After the activated carbon step, the TOC was 42.6 mg/l and the turbidity, 620 JTU.

The second sequence (I in Figure 33) involved foam fractionation carbon sorption and 0.45-μ Millipore filtration of the diluted sample. The foam fractionation process concentrated very little ROC in the foam and reduced both the concentrations of VOC and ROC only minimally in the effluent. The foam collected after three separate additions of detergent appears to have extracted a significant amount of VOC from the samples, but this might have been misleading due to mass balance, since only a small volume of collapsed foam was generated after each addition. (Note that this is a different kind of experiment from that in which only one addition of detergent but three fractions of foam from the same addition were involved). The activated carbon

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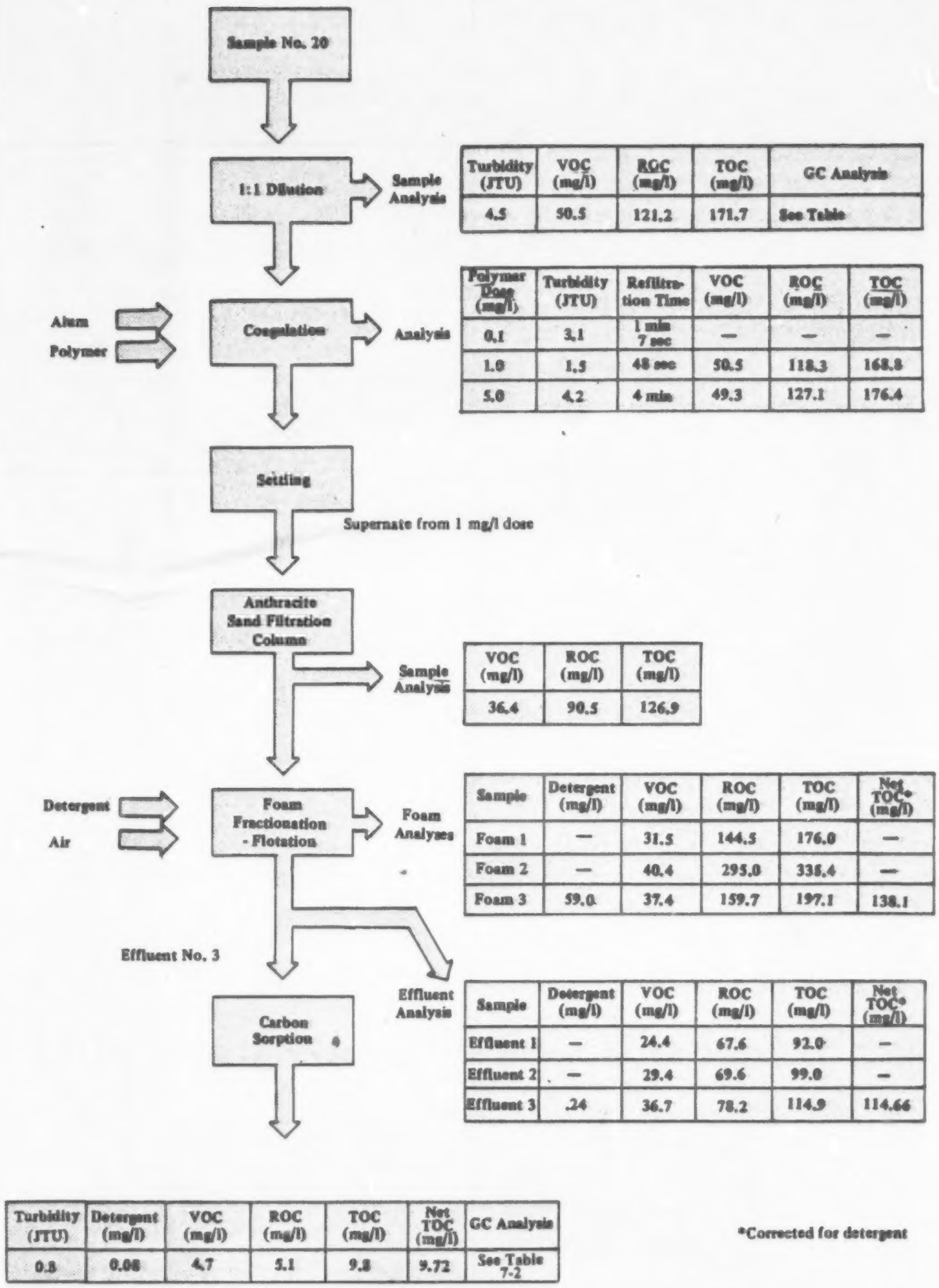
Sample No. 20
1:1 Dilution
Sample Analysis
Alum
Polymer
Coagulation
Analysis
Settling
Supernate from 1 mg/l dose
Anthracite Sand Filtration Column
Sample Analysis
Detergent
Air
Foam Fractionation - Flotation
Foam Analyses
Effluent No. 3
Effluent Analysis
Carbon Sorption

Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)	GC Analysis
4.5	50.5	121.2	171.7	See Table

Polymer Dose (mg/l)	Turbidity (JTU)	Refiltration Time	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)
0.1	3.1	1 min 7 sec	—	—	—
1.0	1.5	48 sec	50.5	118.3	168.8
5.0	4.2	4 min	49.3	127.1	176.4

VOC (mg/l)	ROC (mg/l)	TOC (mg/l)
36.4	90.5	126.9

Sample	Detergent (mg/l)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)	Net TOC* (mg/l)
Foam 1	—	31.5	144.5	176.0	—
Foam 2	—	40.4	295.0	335.4	—
Foam 3	59.0	37.4	159.7	197.1	138.1

Sample	Detergent (mg/l)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)	Net TOC* (mg/l)
Effluent 1	—	24.4	67.6	92.0	—
Effluent 2	—	29.4	69.6	99.0	—
Effluent 3	.24	36.7	78.2	114.9	114.66

Turbidity (JTU)	Detergent (mg/l)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)	Net TOC (mg/l)	GC Analysis
0.8	0.08	4.7	5.1	9.8	9.72	See Table 7-2

*Corrected for detergent

Figure 32. Treatment of nonmetallic toxic wastes, sample no. 20.

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step reduced the TOC by a factor of 5, and the turbidity by a factor of 3. Subsequent Millipore filtration (0.45 μ) dramatically reduced turbidity but had no significant effect on TOC, which is not surprising. Actually, the turbidity prior to Millipore filtration was probably due principally to the presence of finely divided activated carbon particles.

The third sequence (III in Figure 33) involved coagulation with alum and polymer, anthracite-sand filtration, and activated carbon sorption of the diluted sample. Coagulation was optimized with 14 mg/l alum and 0.5 mg/l polyelectrolyte. Such coagulation reduced turbidity by an order of magnitude from 165 to 12 JTU. The filtration and sorption steps taken together were highly effective in reducing TOC from 85.4 to 3.2 mg/l and turbidity from 165 to 0.5 JTU.

3. Summary

From the experimental results shown in Figures 32 and 33, it can be concluded that, in the specific samples examined, the foam fractionation step under the conditions specified played little or no role in removing TOC. Therefore, since the objective of employing this step is to lower the TOC load on the activated carbon step, the foam fractionation-flotation process in these experiments does not appear to be effective for the function required.

It should be noted that there was little flotable material in the samples examined except after the samples had been treated with alum and polyelectrolyte, both of which are recognized as flotation aids. However, the coagulation step produced such an easily settled sludge that it was obviously advantageous to settle it and decant the supernate for subsequent foam fractionation rather than float the coagulum. It is recognized, however, that foam fractionation-flotation has been demonstrated to be a very useful technique for separating appropriate substances from water. If applicable to all toxic organic wastes generated in Ventura County, coagulation would have the following advantages:

a. The sludge from coagulation is much more concentrated than a liquid fraction resulting from a collapsed foam.

b. The organics in the sludge would thus be more easily and more economically destroyed or disposed of than the liquid concentrate from the collapsed foam.

c. There is very little tendency for volatile organics to escape to atmosphere in coagulation as compared to foam fractionation.

The results also indicate that dual-media filtration removed a considerable proportion of the TOC simultaneously with the removal of alum floc, as expected. Thus, dual-media filtration should obviously be placed upstream of the activated carbon sorption step, so as to minimize in a very simple way carbon regeneration and/or replacement.

It should be recognized that any waste brought into the treatment facility may be contaminated by heavy metals and liquids that might prevent those heavy

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TABLE 8. CHROMATOGRAPHIC ANALYSIS OF TREATED AND UNTREATED SAMPLE NO. 20

Raw Sample (Diluted 1:1)			Coagulated, Anthracite-Sand Filtered, Foam-Fractionated, and Carbon-Sorbed Sample		
Peak No.	Retention Time (Min.)	Integrated Area	Peak No.	Retention Time (Min.)	Integrated Area
1[a]	0.37	37,725,094	1[a]	0.37	45,305,994
2	0.68	2,654,836	-	-	-
3	1.88	591,040	-	-	-
4	3.11	460,241	4	3.11	3,185
5	4.76	56,149	-	-	-
6	5.21	37,143	-	-	-
7	5.26	13,468	7	5.26	4,796
8	5.34	299,314	-	-	-
-	-	-	9	7.24	126
10	8.23	8,933	-	-	-
11	8.36	4,043	-	-	-
12	8.90	66,998	12	8.89	2,273
13	-	-	13	8.99	6,550
14	10.06	2,859	-	-	-
15	10.08	5,434	-	-	-

[a] Hexane

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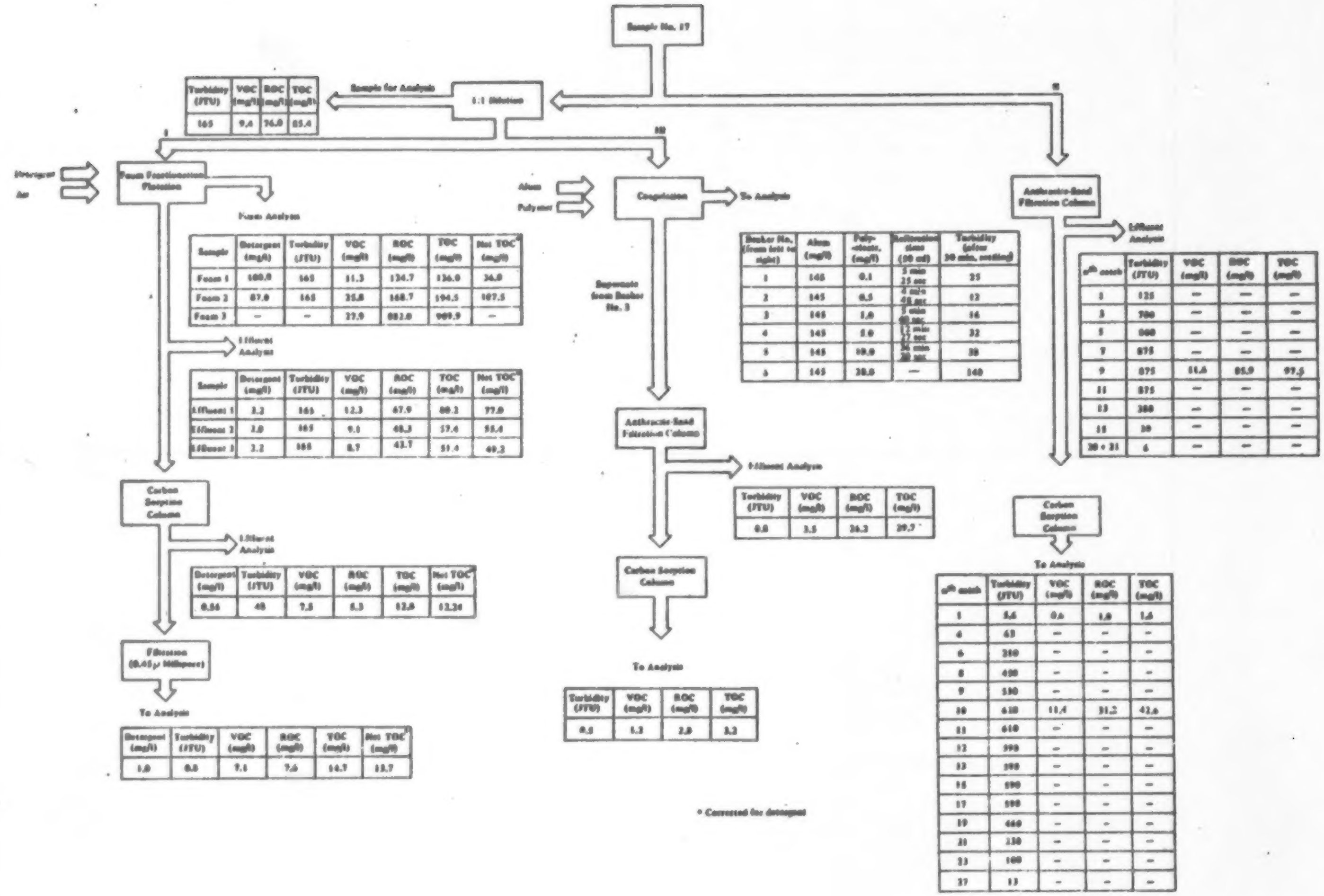
Sample No. 17
1:1 Dilution
Sample for Analysis
I
II
III
Detergent
Air
Foam Fractionation Flotation
Foam Analysis
Effluent Analysis
Carbon Sorption Column
Effluent Analysis
Filtration (0.45μ Millipore)
To Analysis
Alum
Polymer
Coagulation
To Analysis
Supernate from Beaker No. 3
Anthracite-Sand Filtration Column
Effluent Analysis
Carbon Sorption Column
To Analysis
Anthracite-Sand Filtration Column
Effluent Analysis
Carbon Sorption Column
To Analysis

Sample for Analysis

Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)
165	9.4	76.0	85.4

Foam Analysis

Sample	Detergent (mg/l)	Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)	Net TOC* (mg/l)
Foam 1	100.0	165	11.3	124.7	136.0	36.0
Foam 2	87.0	165	25.8	168.7	194.5	107.5
Foam 3	–	–	27.9	882.0	909.9	–

Effluent Analysis

Sample	Detergent (mg/l)	Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)	Net TOC* (mg/l)
Effluent 1	3.2	165	12.3	67.9	80.2	77.0
Effluent 2	2.0	165	9.1	48.3	57.4	55.4
Effluent 3	2.2	165	8.7	42.7	51.4	49.2

Effluent Analysis

Detergent (mg/l)	Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)	Net TOC* (mg/l)
0.56	48	7.5	5.3	12.8	12.24

To Analysis

Detergent (mg/l)	Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)	Net TOC* (mg/l)
1.0	0.8	7.1	7.6	14.7	13.7

Beaker No. (from left to right)	Alum (mg/l)	Polyelectr. (mg/l)	Sedimentation time (50 ml)	Turbidity (after 30 min. settling)
1	145	0.1	5 min 25 sec	25
2	145	0.5	4 min 48 sec	12
3	145	1.0	5 min 40 sec	16
4	145	5.0	12 min 17 sec	32
5	145	10.0	34 min 20 sec	38
6	145	20.0	—	140

Effluent Analysis

Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)
0.8	3.5	26.2	29.7*

To Analysis

Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)
0.5	1.3	2.0	3.2

Effluent Analysis

n^{th} batch	Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)
1	125	—	—	—
3	700	—	—	—
5	900	—	—	—
7	875	—	—	—
9	875	11.6	85.9	97.5
11	875	—	—	—
13	380	—	—	—
15	30	—	—	—
20 + 21	6	—	—	—

To Analysis

n^{th} batch	Turbidity (JTU)	VOC (mg/l)	ROC (mg/l)	TOC (mg/l)
1	5.6	0.6	1.0	1.6
4	63	–	–	–
6	300	–	–	–
8	490	–	–	–
9	530	–	–	–
10	610	11.4	31.2	42.6
11	610	–	–	–
12	590	–	–	–
13	590	–	–	–
15	590	–	–	–
17	590	–	–	–
19	460	–	–	–
21	330	–	–	–
23	100	–	–	–
27	13	–	–	–

* Corrected for detergent

Figure 33. Treatment of nonmetallic toxic wastes: sample no. 12.

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metals from being precipitated along with the alum by simple basic coagulation. It is necessary, therefore, to examine for amounts of heavy metals in the final effluent from the treatment sequence used for removing toxic substances from so-called "nonmetallic" wastes. In the event that unacceptable levels of heavy metals are present, the effluent would have to be processed in the metallic waste treatment sequence.

On the basis of the test results summarized in this chapter and the nature of wastes in the County, it is apparent that batch process treatment technology would be most appropriate. Complete flexibility is needed to treat specific waste by processes identified for several types of wastes, such as heavy metal wastes, that also contain organics. These tests have led to the conceptual design of facilities.

Sludge Dewatering/Thickening--

Although sludge dewatering is an important part of the waste treatment process for each category of liquid wastes encountered in this study, the actual volume of dewatered sludge (*the solids loading*) from each category is quite small. This limited the scope of the bench-scale tests for the operation of simulated industrial equipment. Enormously large samples of dilute waste streams would have had to be treated in the bench-scale processes in order to produce sufficient sludge quantities. The bench-scale studies were necessarily *fundamental* in nature, due to the nature of sludge dewatering equipment commercially available. In general, commercial dewatering equipment is based on six fundamentally different unit operations: gravity thickening (as in a tank), gravity dewatering (as through a filter), centrifugation, vacuum filtration, filter pressing, and so-called "sludge tumbling."

The tests performed included settling velocity and compaction for gravity thickening, floc agglomeration, floc interface formation (the ability of the floc to separate to leave a clear supernatant), floc blinding of filter media, centrifugation and vacuum filtration; floc adhesion in filter pressing; and sludge tumbling as in the sludge consolidation step in certain types of gravity dewatering equipment.

Metal Precipitation Sludges--The most important step in producing a metal hydroxide sludge or a metal sulfide sludge or indeed almost any kind of sludge which will settle quickly, thicken rapidly and adequately, and be susceptible to effective dewatering, is the *coagulation* and *flocculation* step. This step depends primarily on the selection of an adequate polyelectrolyte. Often the settled and thickened sludge will have additional polyelectrolyte or polyelectrolytes added between the thickening and dewatering steps. Selection of the best polyelectrolyte is also important in assuring that the filtration of the supernates resulting from coagulation and flocculation is efficient and thorough.

1. Hydroxide sludges

In the second series of studies of the Treatment of Metallic Wastes shown in Figure 30, certain settling tests were performed on the hydroxide sludges generated by the treatments involving the destruction of cyanides. First, without a coagulation aid (polyelectrolyte), a *slurry* of the material

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resulting from the second stage of the destruction (pH 8.5, see Figure 30) was transferred to a settling tube (see Bench-Scale Equipment, Materials and Tests), which was maintained in the vertical position. The bulk of the sludge settled 52 cm (about 1/3 of the height of the tube) in ten minutes. The supernate was not entirely clear throughout its entire height at this time. After forty minutes, the settled sludge volume was 1/3 of the initial height of the slurry, and the supernate was quite clear. Because of the need for all of this material for use in the remaining treatments in the sequence (see Figure 30), no other experiments were carried out on this material at the time. It was simply concluded that this sludge was rather quickly settled and compacted. This indicated that a sludge of this type could be concentrated in a gravity thickening tank.

2. Combined sludges (hydroxides and sulfides)

In the same sequence of treatments, in which the hydroxide sludges were tested for settling and compaction in a vertical tube, samples were later taken immediately after the sulfide precipitation (see Figure 30, Sequence 1). This slurry was an extremely finely divided, slowly settling colloidal system. In order to condition this slurry for adequate settling and dewatering, a systematic coagulation study had to be carried out. These experiments were conducted using techniques described in Bench-Scale Equipment, Materials and Tests.

A review of the literature of Camp[1] indicated that the parameter Gt (the velocity gradient, G, multiplied by time, t) generally ranges between 20,000 and 200,000 for optimum flocculation (CGS units). Later investigators determined that Gt of the 20,000 is especially applicable to waters containing a high particulate concentration, such as those found in wastewater treatment. For this reason, a Gt of 22,500 (50 rpm for 15 minutes in the apparatus used here) was selected for laboratory experimentation.

The influence of mean velocity gradient G was tested by coagulation of a dilute suspension of the combined metal hydroxide sulfide precipitates by studying G from 25 sec^{-1} to 50 sec^{-1} and 80 sec^{-1}, while maintaining the Gt product constant (Table 9). The result of these experiments revealed that the best refiltration time was obtained with a mean velocity gradient G of 25 sec^{-1} for a duration of 15 minutes.

Further experiments showed the variation of a refiltration times for a coagulated suspension of metal precipitates as a function of the polymer used (Figure 34). The ability of the polymers to improve refiltration times increased with the increased molecular weight/ionic nature of the polymers. As shown in Figure 34, the highest cationic polymer effected the best time. The shortest refiltration time appeared, however, at about the same dose for all the cationic polymers examined. The same dose resulted also in the fastest settling flocs. The costs of the various polymers from various vendors could not be ascertained for the time and volume that the various polymers might be

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[1] Camp, T.R. "Flocculation and Flocculation Basins," *Transactiona American Society of Civil Engineers*: 120, 1955, 1-16.

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TABLE 9. EFFECT OF G AND t ON THE COAGULATION OF COMBINED METAL HYDROXIDE AND SULFIDE PRECIPITATES[a] USING MEDIUM-HIGH CATIONIC POLYMER

Experimental Conditions	Refiltration Time (Sec)
$G = 25\ sec^{-1}$ $t = 15$ min	53
$G = 50\ sec^{-1}$ $t = 7.5$ min	63
$G = 80\ sec^{-1}$ $t = 4.7$ min	65

[a] Total Suspended Solids (TSS) = 1112.4 mg/l, (after dilution).

used in the proposed VRCSD plant. Therefore, it was decided to conduct all subsequent experiments using a medium-high cationic polymer (Hercofloc 855). It was observed that essentially all dosages of this polymer produced very consolidated, large floc particles, which are conducive to fast settling and easy dewatering.

The slurry resulting from treatment with the optimum dosage of polymer was first tested in the settling tube with the tube in the vertical position. Afterwards, in another test, following reslurring, the test was recorded with the tube inclined at an angle of approximate 60° from the horizontal. In the vertical position test, it was immediately noticed that a very substantial proportion of the floc settled very rapidly but that some of it, including large flocs, "churned." The word "churned" is used to connote the fact that the floc would go down and then up and down, etc., depending on how it collided with other "churning" flocs. The phenomena are best visualized by examining the photographs marked (a) and (b) in Figure 34. These photographs show the enormously large flocs still remaining in a suspended state 57 seconds after placing the slurry in the tube. Notice, however, that a large proportion of the floc has descended to the bottom of the tube and that the large flocs above the compact zone are in a perfectly clear aqueous phase. This picture shows the bottom half of the tube. A photograph, marked (b), taken of the upper half of the tube only 1 or 2 seconds before taking the photograph marked (a), also shows very large flocs (which are observed to be "churning") in clear liquid and a zone of small flocs at the top in a liquid containing very slight turbidity. These small flocs had actually floated to the top.

Examination of the "churning" flocs revealed the presence of tiny bubbles of unknown origin. Afterwards, it was also noticed that in certain of the coagulation test beakers the flocs tended to separate into essentially two layers. A bottom layer which, although containing flocs with attached bubbles, consisted of flocs sufficiently heavier than the aqueous phase to sink eventually, and a top layer, which contained flocs with attached bubbles which had

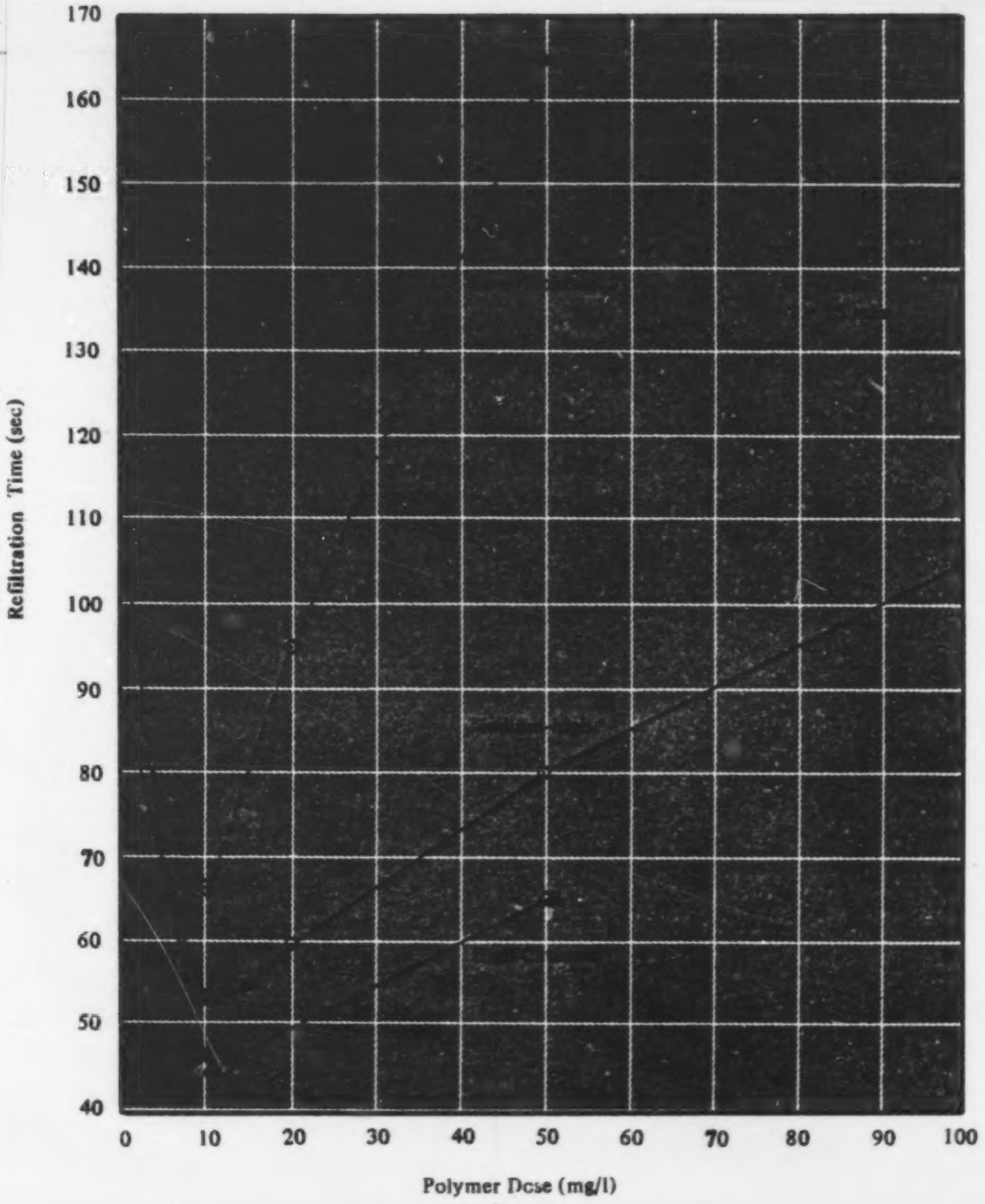

Figure 34. Effect of cationic hercofloc polymers on suspension of metal hydroxide and sulfide precipitates.

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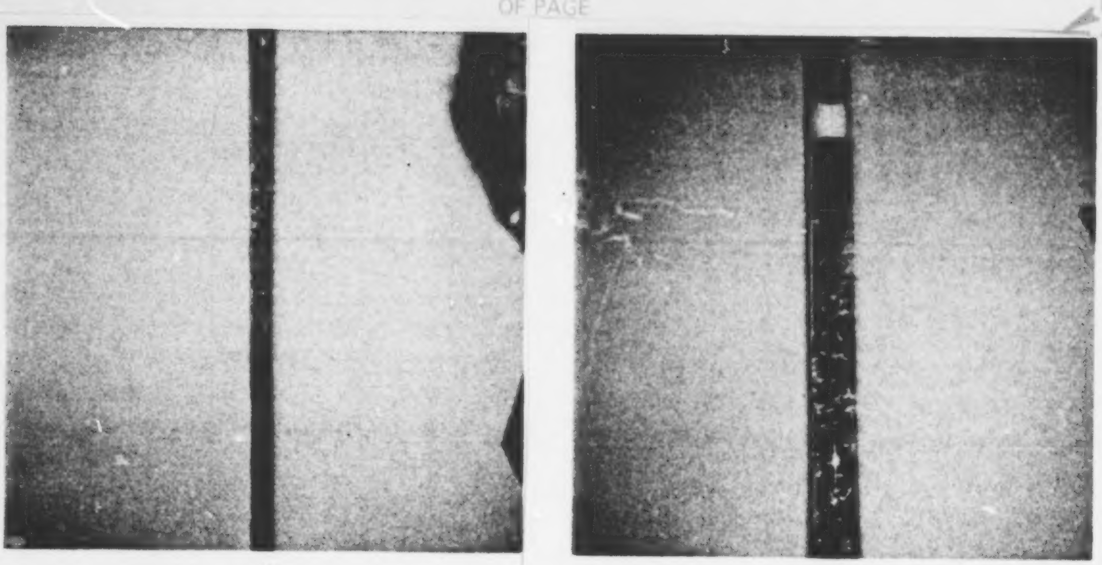

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Figure 35. Settling of coagulated metal precipitates in the vertical tube.

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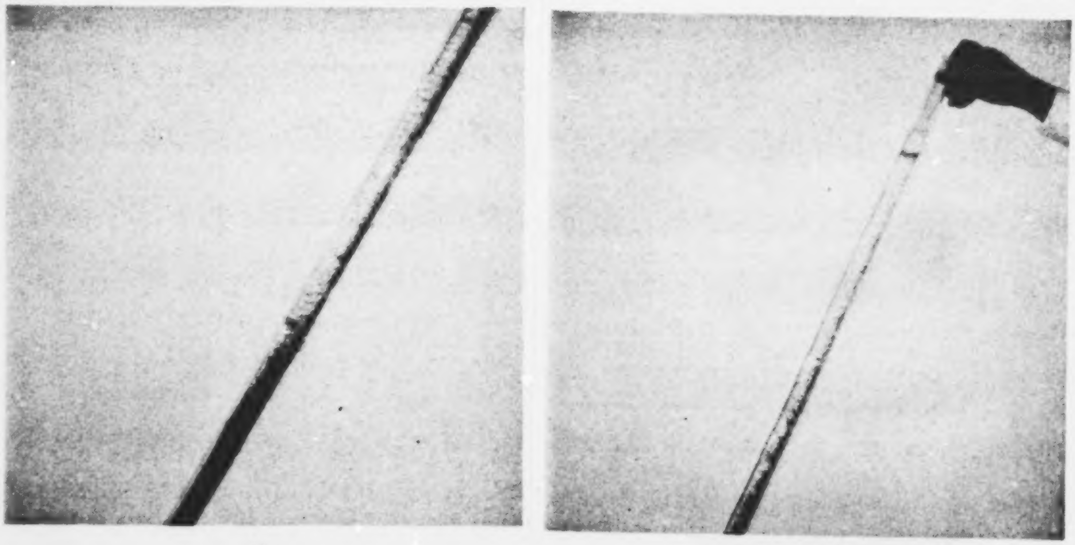

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Figure 36. Settling of coagulated metal precipitates in the inclined tube.

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rendered the flocs light enough to float.

When the tube was inclined at 60° after reslurring the floc in the settling tube, the tendency for the floc to settle (in the same interval as before) into a clear supernatant that contained very few large flocs and a highly compacted floc layer at the bottom of the tube was greatly improved, compared to the behavior in the vertical position (see the photograph marked (a) in Figure 36). Smaller flocs were still churning in the tube, however, and some floc was floated to the top of the tube (see the photograph marked (b) in Figure 36). It was found that simply returning the liquid and floc to the coagulation vessel and stirring at 50 rpm for a few minutes removed the tiny bubbles from the flocs and, therefore, conditioned the floc so that it settled completely and rapidly, particularly in the inclined tube. It was concluded again that under the proper conditions of coagulation and flocculation the mixed precipitates (OH^- and $S^{=}$) settled quite adequately.

The settled flocs were decanted and placed in a centrifuge tube and centrifuged at 4,000 rpm for 15 minutes. The very clear centrate was decanted the floc was transferred to a vacuum filter (Millipore apparatus, Whatman glass fiber filter, 17 inches Hg vacuum), and after the small liquid phase had passed through the filter, another filter was placed on the top of the filter, and slight pressure was applied to the beaker by hand. The resulting solids pellet was firm with no tendencey to "drip" a liquid phase. This adequately coagulated, and settled sludge was, therefore, judged by these fundamental tests to be very easy to dewater by gravity settling and thickening followed by (a) centrifugation, (b) vacuum filtration, and (c) filter pressing.

In order to observe the probable behavior of the solids by gravity dewatering on a rotating screen, a sample of the centrifuged sludge was placed on a 100-mesh, monofilament, nylon screen and rolled and tumbled. After removing the consolidation sludge, the back surface of the screen, which, as expected, was contaminated by a small proportion of sludge, was washed briefly with running water. The sludge was easily removed, thus indicating that gravity dewatering followed by sludge tumbling on a screen would also be effective in concentrating and dewatering the sludge.

3. Other sludges

There was not enough material collected in any of the procedures for determining sample characteristics or liquid treatability to obtain meaningful nonmetallic sludge dewatering data, other than that subjective data recorded on Figures 31 and 32. The amount of such sludges at the prototype is expected to be very small so that they could be periodically hauled to a Class I landfill or blended with the metallic sludges prior to dewatering and disposal.

In view of the small quanity and uncertain nature of sludges expected from prototype operation, the apparent best sludge management system is one involving inexpensive gravity thickening followed by mechanical dewatering with a device found to be optimal through prototype-scale pilot testing. This procedure involves use or rental of pilot-scale units, such as centrifuges or filter presses on-site to test solids capture and cake moisture content as a function of chemical and operational variables. Most vendors in the area are

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happy to make available such pilot units at little or no cost. The most cost-effective dewatering equipment can then be easily identified and purchased for permanent installation.

Prototype Plant Design Considerations, Cost Estimates and Operations

On the basis of the Bench-Scale Testing Program conducted for the prototype Residual Waste Treatment (RWTP), the conceptual design should be modified somewhat from that anticipated in the Preliminary Planning step. This section highlights these modifications and summarizes some of the practical operational considerations of the prototype plant.

Conceptual Design--

The fundamental change in the preliminary design consists of abandoning continuous flow processes in favor of batch processes. The widely varying nature of the wastes, the smaller projected volumes of wastes received, and the complexity of certain wastes led to this decision.

A schematic diagram of the proposed treatment plant is presented in Figure 37. Processes shown consist mainly of duplicated units to permit batch operation. While one process is going on in one unit, its duplicate can be emptied and/or filled in preparation for treatment of the next batch.

The basic process units are essentially the same as those anticipated prior to the Bench-Scale Testing Program, with the following exceptions:

1. Tank volumes are smaller but are duplicated.
2. Foam fractionation-flotation is replaced by dissolved air flotation.
3. Dual-media filters and carbon sorption processes are duplicated for processing heavy metal and nonmetallic wastes separately.
4. Optional reclamation processes, namely, ion exchange softening and reverse osmosis units, are not shown but are still considered optional if reuse is desired or certain difficult-to-treat wastes must meet discharge standards.

The facilities shown in Figure 37 must still be considered conceptual at this stage. A very extensive predesign evaluation is warranted to minimize all unnecessary redundancy but still maintain sufficient flexibility for the operational staff to treat a wide variety of residual wastes with unpredictable quality.

The layout of the prototype facilites is shown in approximate scale in Figure 38. The site is located immediately west of the VRCSD's existing Liquid Waste Treatment Plant (LWTP) at Montalvo. The residual waste treatment facilities would require approximately one-half hectare of land. The site is presently used as percolation lagoons. Necessary filling and compaction would be required, but additional land area would not have to be purchased.

The arrangement of process units, buildings, and yard piping is only a "first cut" approximation. Predesign optimization would probably result in some significant rearrangment. Nevertheless, Figure 38 illustrates the desirable concepts of (a) integrating the truck patterns with those of the

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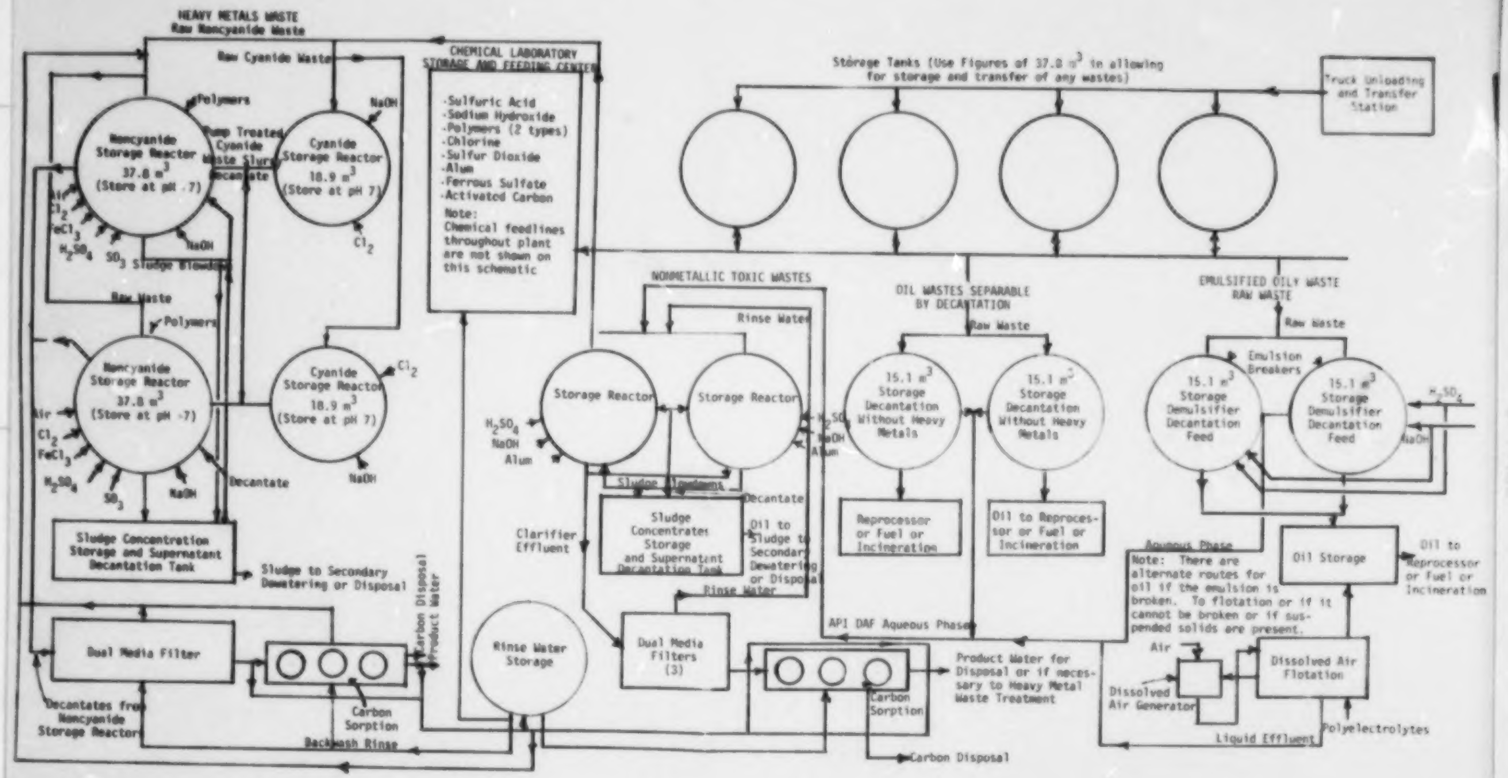
HEAVY METALS WASTE
Raw Noncyanide Waste
Raw Cyanide Waste
Polymers
Noncyanide Storage Reactor 37.8 m³ (Store at pH ~7)
Pump Treated Cyanide Waste Slurry
Decantate
Cyanide Storage Reactor 18.9 m³ (Store at pH 7)
NaOH
Cl2
Air
FeCl3
H2SO4
SO3
Sludge Blowdown
Raw Waste
Sludge Concentration Storage and Supernatant Decantation Tank
Sludge to Secondary Dewatering or Disposal
Dual Media Filter
Carbon Sorption
Carbon Disposal
Product Water
Backwash Rinse
Decantates from Noncyanide Storage Reactor
CHEMICAL LABORATORY STORAGE AND FEEDING CENTER
·Sulfuric Acid
·Sodium Hydroxide
·Polymers (2 types)
·Chlorine
·Sulfur Dioxide
·Alum
·Ferrous Sulfate
·Activated Carbon
Note: Chemical feedlines throughout plant are not shown on this schematic
Rinse Water Storage
Storage Tanks (Use Figures of 37.8 m³ in allowing for storage and transfer of any wastes)
Truck Unloading and Transfer Station
NONMETALLIC TOXIC WASTES
Rinse Water
Storage Reactor
Storage Reactor
Alum
Sludge Blowdown
Clarifier Effluent
Sludge Concentrates Storage and Supernatant Decantation Tank
Oil to Sludge to Secondary Dewatering or Disposal
Dual Media Filters (3)
API DAF Aqueous Phase
Product Water for Disposal or if necessary to Heavy Metal Waste Treatment
OIL WASTES SEPARABLE BY DECANTATION
15.1 m³ Storage Decantation Without Heavy Metals
Reprocessor or Fuel or Incineration
Oil to Reprocessor or Fuel or Incineration
EMULSIFIED OILY WASTE RAW WASTE
Emulsion Breakers
15.1 m³ Storage Demulsifier Decantation Feed
Aqueous Phase
Note: There are alternate routes for oil if the emulsion is broken. To flotation or if it cannot be broken or if suspended solids are present.
Oil Storage
Oil to Reprocessor or Fuel or Incineration
Dissolved Air Flotation
Dissolved Air Generator
Liquid Effluent
Polyelectrolytes

Figure 37. Treatment facility schematic.

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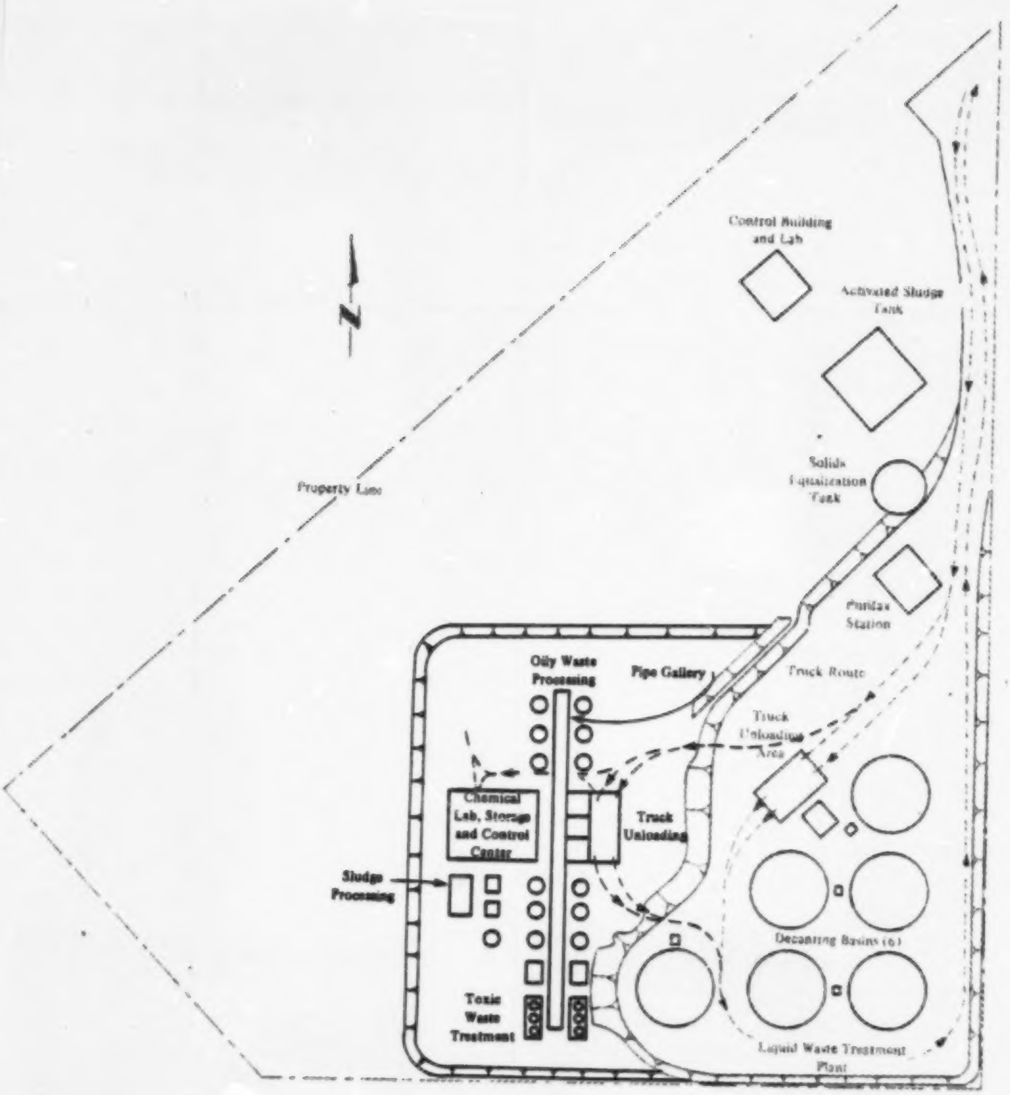
N
Property Line
Control Building and Lab
Activated Sludge Tank
Solids Equalization Tank
Purifax Station
Pipe Gallery
Truck Route
Truck Unloading Area
Oily Waste Processing
Chemical Lab, Storage and Control Center
Truck Unloading
Sludge Processing
Toxic Waste Treatment
Decanting Basins (6)
Liquid Waste Treatment Plant

Figure 38. Montalvo site possible plot plan.

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LWTP, (b) locating similar process units in clusters, (c) providing access to each tank and treatment unit, (d) having a central laboratory, storage, and control facility, and (e) providing an accessible pipe gallery to enable rapid modifications of yard piping if needed for process modification.

As presently envisioned, trucks would unload immediately upon arrival. Their wastes would be discharged by gravity into one of our 37.8-cubic-meter-capacity holding tanks. Characterization tests would be performed on the wastes to determine the appropriate treatment processes to employ. The wastes would then be pumped into the appropriate treatment/storage tanks, and treatment would begin.

At any time, treatment could be terminated and the treatment tanks drained by gravity into one of the four holding tanks. The wastes could subsequently be pumped into another processing unit or back to trucks for Class I land disposal, if necessary.

All tanks should be constructed of corrosion-resistant materials, most likely constructed of or lined with reinforced fiberglass. Tank bottoms would be conical or hopper shaped to permit ready removal of sediment without expensive scraper mechanisms.

Neither Figures 37 nor 38 show all of the piping, feeding, and transport facilities because of their complexity. Chemical feeding would be achieved primarily by metering pumps controlled by liquid quality monitoring equipment with feedback signals regulating the amount of chemicals added. It may be possible to feed more than one tank per unit; however, separate controls are envisioned for most units. Appropriate valving would prevent some duplication of chemical feeding facilities.

The conceptual design also shows on-site laboratory facilities to include rapid characterization of wastes and monitoring and progress and efficiency of treatment process units. As shown in the Cost Estimates, equipping the laboratory will cost approximately $70,000 in addition to permanent fixtures such as sinks, countertops, hood, etc. It is recognized that the Oxnard Wastewater Treatment Plant and the City of San Buenaventura both have extensive laboratories for analysis of wastewaters; however, the costs of the local laboratory facilities are justified by the necessary convenience to run the RWTP. The time delay and travel expense of transporting samples to a remote laboratory would seriously hinder operational efficiency. Also, visual observations of the waste characterization tests by operating personnel would be lost if samples were tested remotely. Such observations are expected to be very important for successful selection of treatment processes for each waste.

Cost Estimates--

Itemized descriptions and cost estimates for the RWTP and its laboratory are given in Tables 10 and 11, respectively. Item 8 of Table 10 includes all items of Table 11. The cost estimates are considered to be within 30 percent of the actual costs.

Capital costs total $1,472,000. This value is approximately the same as that anticipated for the facilities during the preliminary planning stage,

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even though flows to be treated are smaller than anticipated. The updated figures allow extra money for more extensive earthwork than used previously to reflect the fact the plant would be located on fill material. Also, the laboratory facilities shown herein would be permanent as opposed to the trailer lab assumed previously.

Operation and maintenance costs are difficult to measure because of the unknown quantity of chemical required to effect treatment; however, the following is an approximation:

TABLE 10. ESTIMATED CAPITAL COSTS

Item		Cost[1] (Thousand Dollars)
No.	Description	
1	Storage and process tanks (circular)	
	6 - 37.8 M^3	67
	2 - 22.7 M^3	15
	2 - 18.9 M^3	12
	4 - 15.1 M^3	22
2	Sludge concentration and handling	60
3	Dissolved air flotation	15
4	Dual media filters and carbon sorption	80
5	Chemical storage and feed system (includes sulfuric acid, sodium hydroxide, polymers, chlorine, sulfur dioxide, alum, ferrous sulfate, and activated carbon)	120
6	Site work, concrete pads, misc. structures, etc.	250
7	Misc. mechanical equipment, piping, transfer, and process pumps	130
8	Control building (lab, storage, etc.)	170
9	Electrical, instrumentation, panels, etc.	130
	Subtotal Contingencies (15%)	1,071 160
	Construction cost Engineering, legal, admin. (20%)	1,231 241
	Total	1,472

[1] November, 1976 costs (ENR = 2915)

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TABLE 11. LABORATORY FACILITIES AND COST ESTIMATES

Item		Cost* (Dollars)
No.	Description	
1	Atomic Absorption Spectrometer	15,000
2	Gas Chromatograph	13,000
3	Total Organic Carbon Analyzer	11,000
4	Strip Chart Recorders (2)	3,000
5	Muffle Furnace	900
6	Centrifuge	400
7	Colorimeter	600
8	Drying Oven	400
9	Freezer	500
10	COD Apparatus	300
11	pH Meter	500
12	Multiple Electrodes	2,000
13	Mixers (Magnetic and Jar Test)	500
14	Conductivity Meter	800
15	Flame Photometer	600
16	Refrigerator	500
17	Samplers (2)	2,500
18	Balance	2,000
19	Turbidimeter	500
20	Miscellaneous Standard Glassware, Chemicals, and Supplies	5,500
	Subtotal	60,700
	Contingencies (15%)	9,100
	Total	69,800

*November, 1976 costs (ERN = 2915)

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Category	Annual Cost (Dollars)
Operator Salaries	
Chief	25,000
Chemist	20,000
Staff (2 at 15,000 ea)	30,000
Chemicals	40,000
Maintenance of Facilities	20,000
Power	10,000
Miscellaneous (Lab Supplies, Improvements, etc.)	10,000
TOTAL	$155,000

Amortized capital at 7% interest for 20 years would total approximately $139,000. The total annual costs would therefore be, approximately $294,000.

Operations--

As presently conceived, the RWTP would be operated by four people on a 7-day/week single 8-hour shift. The positions are given in the above annual cost tabulation. Security would be provided at all times in concert with present security at the Montalvo and LWTP facilities.

The importance of highly competent operator personnel cannot be overemphasized. Treating residual wastes is the most complicated operational challenge in modern waste treatment. Many of the wastes will be toxic, and accidents due to lack of knowledge or care would easily be fatal. For example, toxic cyanides will best be stored and treated at the site. They are stable at high pH values but emit lethal HCN gas if the pH is accidentally lowered too far.

For these reasons, the operator and chemist must be highly trained and well compensated. Both should have a minimum of a B.S. or M.S. in college chemistry and experience with toxic wastes. All other plant personnel should be well versed in the chemistry and safety precautions of toxic wastes.

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SECTION 5

RESIDUAL ORGANIC WASTES

PRELIMINARY PLANNING

Initial planning envisioned the use of a pyrolysis treatment scheme to reduce the anticipated problem organic wastes in Ventura County. An analysis of the pyrolysis process focused upon ensuring that each component is technically feasible, and then modifying or reducing the total process as a result of recent developments in pyrolysis and economic considerations in order to develop a suitable demonstration program.

A 90.7 metric-ton-per day pyrolysis facility was analysed. The feed to the facility consisted of a mixture of municipal wastewater sludge, meat and fish processing wastes, cannery wastes, animal manures, and small amounts of oily sludge and oil from brines. The resulting economics indicated that alternative means of managing the residual organic waste in Ventura County should be considered. In addition, it appeared that residual organic wastes should not be mixed together for treatment at a central facility.

The development and evaluation of alternative management schemes were guided by the following primary considerations:

1. The plan must be capable of handling both present and projected organic solids on a full-time year-round basis.
2. The recommended system must be reliable with inherent flexibility.
3. The program must be acceptable to the community.
4. Every environmental effect of the project must be minimized.
5. The plan must be cost-effective.

The following studies were developed to generate the necessary data and information to develop and evaluate alternative management schemes:

1. Analyze and summarize organic waste quantities in Ventura County.
    a. Determine current and 10-year estimates using existing trends where available organic wastes produced daily in Ventura County from the following categories:

        1) Municipal wastewater sludges
        2) Animal Manures
        3) Vegetable and produce packing wastes
        4) Meat and fish processing wastes

   b. Survey waste quantities in Ventura County, including plant interviews, distribution of questionnaires, and completion of information. Visit and interview approximately 40 establishments, including wastewater treatment plants, industries, landfills, farms, and feedlots.

   c. Present waste quantities on a wet and dry weight basis, both daily and yearly average quantities. Characterize the wastes, including moisture content, volatile content, fertilizer value, and caloric value as pertinent.

   d. Inventory current practices for treatment, handling, and disposal of wastes for each category in Ventura County.

   e. Identify present day or potential problems (10 years) associated with current treatment, handling, and disposal techniques, including major social, environmental, institutional and economic considerations.

2. To analyze treatment, handling, and disposal alternatives.

   a. Review the current state-of-the-art for treatment, handling, and disposal of the organic wastes specified in each category of this study.

   b. Analyze alternative systems and propose feasible alternatives if needed to handle problem areas, including nonstructural solutions indicating which solutions appear to have merit for final analysis.

   c. Generate cost estimates for each of the proposed solutions and discuss briefly the major social and environmental considerations of each.

   d. Break down cost estimates into capital costs, including total, annual, and per metric ton of capacity, where applicable, operations costs, and maintenance costs.

   e. Compare the cost and associated social and environmental considerations for each of the proposed solutions with the present treatment, handling, and disposal methods.

ORGANIC WASTE SURVEY

Organic wastes in Ventura County have been categorized as one of four types. They are: (1) municipal wastewater sludges, (2) agricultural wastes, (3) animal manures, and (4) meat/fish processing wastes. Prior to analysis of alternative wastes handling/disposal systems, it was necessary to define quantities of wastes presently produced in Ventura County and project future production. This chapter summarizes methods used to develop waste estimates, inventory current disposal practices, and assign problem status.

Municipal Wastewater Sludges

Fifteen municipal wastewater treatment plants are currently in operation in Ventura County. They are:

1. Oxnard
2. Ventura
3. Thousand Oaks, Hill Canyon
4. Simi Valley
5. Camarillo
6. Santa Paula
7. Oak View
8. Fillmore
9. Piru
10. Montalvo
11. Thousand Oaks, Olsen Road
12. Camarillo State Hospital
13. Moorpark
14. Point Mugu*
15. Saticoy*

Because flows from Point Mugu will soon be diverted to the Oxnard Wastewater Treatment Plant, this plant was dropped from further consideration. The Saticoy treatment system was not considered further, because it utilizes a septic tank system with long intervals between cleanings. Of the remaining thirteen plants, seven have flows exceeding 1 mgd. These plants include Oxnard, Ventura, Thousand Oaks - Hill Canyon, Simi Valley, Camarillo, Santa Paula, and Oak View.

In order to obtain necessary survey data, several techniques for gathering information were used. They included:

1. Review of existing treatment plant facility plans
2. Review of VRCSD data and documents
3. Personal interviews with treatment plant superintendents[2]

---

[2] It was determined that the personal interviews would be necessary for only the Oak View and Camarillo State Hospital wastewater treatment plants.

*Not included in study.

Present sludge production levels and disposal practices were inventoried for all treatment plants. Projections for future sludge production were developed using flow and characterization projections contained in the 208 Areawide Waste Treatment Management Planning Study.

Summary of Quantities--

Both current and projected municipal sludge quantities are shown in Table 12. This table presents daily and yearly average sludge quantities on both a wet and dry basis. Quantities are based on characterization data discussed later in this section. As shown in this table, Oxnard is the largest producer of municipal sewage sludge, contributing nearly 45 percent of the dry weight total for the 13 treatment plants. In Figure 40, municipal wastewater treatment locations and sludge production are shown on a map of the southern half of Ventura County. The large producer of sludges is shown by the larger circles, with smaller circles representing lesser quantities. The key in the upper right corner indicates the relative scale involved. All thirteen treatment plants are listed and their locations are noted on the map as shown. Of considerable significance in the consideration of central processing is the fact that three plants (Oxnard, Ventura, and Camarillo) on a combined basis produce over 70 percent of the county-wide total. This is of significance because of the proximity of the three plants.

Discussion of Present Disposal Methods--

Oxnard--Currently, Oxnard dewaters its raw sludge by vacuum filtration, obtaining the solids cake from approximately 22 percent solids. These solids are then hauled by truck to the Simi Valley Class I landfill site. An incineration process designed to minimize hauling of these waste solids has experienced operational problems and is currently not being used. Digestion tanks are presently under construction and will be operational in the near future. It is expected that the present means of sludge dewatering and disposal will be continued at this plant with quantities increasing every year.

Ventura--The City of San Buenaventura currently uses half of its aeration tanks as aerobic digesters. The aerobically digested sludge is piped across the street to a lot adjacent to the treatment plant where it is disked into the ground. This presents problems both from an odor and a health standpoint. Soil conditions in the acreage across the street are such that little or no filtration occurs. A clay lens, approximately six feet below the ground, keeps the soil above it saturated and of little percolative value. Alternate methods of sludge disposal on days in which disking would not be permitted consist of a Purifax oxidation unit which utilizes chlorine injection at high pressure to oxidize the waste solids. These solids are stored in a holding tank and then decanted for disposal to the Simi Valley landfill site. The projected solids handling and disposal plan for the Ventura wastewater treatment facility includes dissolved air flotation of waste activated sludge solids, digestion of combined waste activated sludge and primary sludge, filter pressing of the combined sludge after treatment with lime and ferric chloride, and hauling of the pressed cake containing approximately 40 percent solids to a suitable landfill site.

Thousand Oaks-Hill Canyon--The Thousand Oaks, Hill Canyon Wastewater Treatment Plant uses two-stage heated anaerobic digestion to treat primary

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TABLE 12. MUNICIPAL SLUDGE SUMMARY

Wastewater Treatment Plant	DAILY AVERAGE (kg/day) Present Dry Weight	Projected Dry Weight	Present Wet Weight	Projected Wet Weight	YEARLY AVERAGE (metric tons/yr) Present Dry Weight	Projected Dry Weight	Present Wet Weight	Projected Wet Weight	Disposal Method
1. Oxnard	13,030	18,310	57,920	81,370	4,750	6,690	21,150	29,700	Vacuum filter digested sludge, truck to landfill, 22.5% solids
2. Ventura	8,050	10,210	20,120	25,510	2,940	3,730	7,340	9,310	Filter press digested sludge, truck to landfill, 40% solids
3. Thousand Oaks Hill Canyon	6,800	12,330	9,720	17,620	2,480	4,500	3,550	6,430	Sun dry, used for sod farm.
4. Simi Valley	4,490	7,460	6,410	10,660	1,640	2,720	2,340	3,890	Sun dry, stockpile, haul excess as necessary.
5. Camarillo	3,180	6,000	4,540	8,570	1,160	2,190	1,660	3,130	Sun dry, used for sod farm.
6. Santa Paula	1,290	1,580	1,850	2,260	470	575	675	825	Sun dry, used as fertilizer by public.
7. Oak View	910	1,380	1,340	1,980	330	510	470	720	Sun dry, disc into soil.
8. Fillmore	290	430	415	620	105	160	150	230	Sun dry, used as fertilizer by public.
9. Piru	150	150	215	215	55	55	75	75	Sun dry
10. Montalvo	105		150		35		55		Discharge to LWTF No. 1, VRCSD
11. Thousand Oaks Olsen Road	100	310	140	435	35	115	50	160	Sun dry, stockpiled on site for disposal as necessary.
12. Camarillo State Hospital	70	70	95	95	25	25	35	35	Sun dry for use by employees.
13. Moorpark	55	120	80	180	20	45	30	65	Sun dry, stockpiled for use by farmers.
TOTAL	38,520	58,350	102,955	149,515	14,045	21,315	37,580	54,570	

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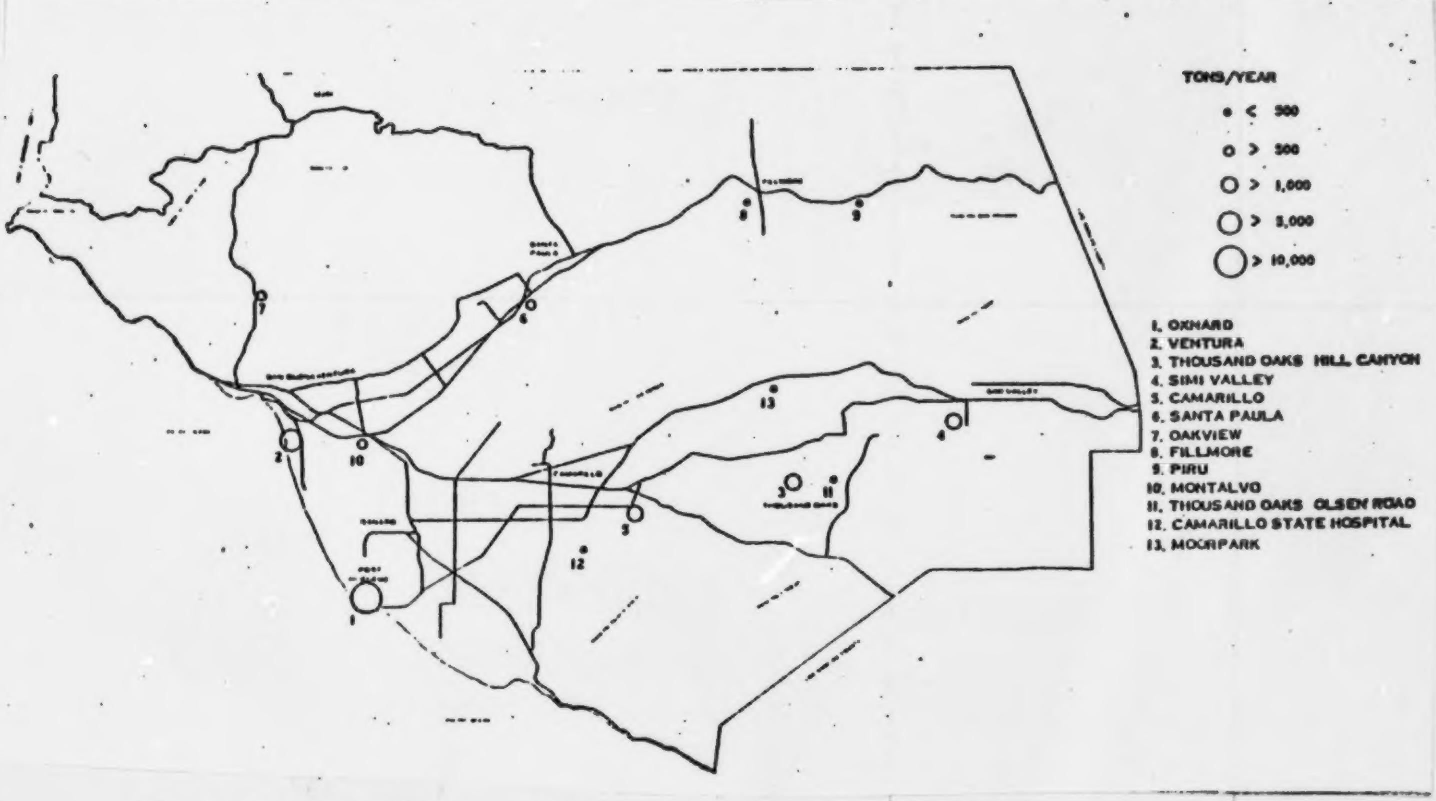
TONS/YEAR
• < 500
○ > 500
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1. OXNARD
2. VENTURA
3. THOUSAND OAKS HILL CANYON
4. SIMI VALLEY
5. CAMARILLO
6. SANTA PAULA
7. OAKVIEW
8. FILLMORE
9. PIRU
10. MONTALVO
11. THOUSAND OAKS OLSEN ROAD
12. CAMARILLO STATE HOSPITAL
13. MOORPARK
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Figure 39. Municipal wastewater treatment plant location and sludge production.

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and biological sludges. After digestion, the sludge is lagooned and then dewatered in drying beds and stockpiled. The Pacific Sod Company has contracted to take all the plant's dried sludge. Problems have been encountered with odors and an odor masking system is used which releases a masking agent into the air when odor problems arise.

Simi Valley--The Simi Valley wastewater treatment facility uses two primary heated tanks for anaerobic sludge digestion. The digested sludge is then placed in three sludge lagoons on a treatment plant site with minimal odor complaints. Later the sludge is sun-dried, stockpiled, and distributed to the public with the excess hauled to landfill as deemed necessary.

Camarillo--The Camarillo wastewater treatment facility uses both anaerobic and aerobic digestion for treatment of wastewater sludges. Primary and secondary anaerobic digesters are used in the treatment of raw primary sludge. The aerobic digestion process is used to treat waste activated sludge and digester supernatant. After digestion, all of the sludge is dried on sand drainage beds and then stockpiled. The Pacific Sod Company hauls all the dry sludge from the site for use as a soil conditioner for growing sod.

Santa Paula--The Santa Paula wastewater treatment facility uses anaerobic digestion in the treatment of sludge. Three digestion units are used in this process. The primary digester is heated and mixed. The secondary digester is only mixed. The final digester is basically a settling tank. After digestion, the sludge is sun-dried and stockpiled for use as a fertilizer by the public.

Oak View--The Oak View wastewater treatment plant uses anaerobic digestion in the treatment of a sludge. A two-stage digestion process is used, after which the digested sludge is piped to acreage adjacent to the plant where it is air-dried and then disked into the soil.

Fillmore--The Fillmore wastewater treatment plant uses a single anaerobic digester which is heated but not mixed. After digestion, the sludge is put on drying beds and then stockpiled. When dry, the ranchers haul it away at their convenience. There appears to be no sludge accumulation problem with the present system.

Piru--The Piru wastewater treatment plant sun dries its sludges. Citrus growers then use it as fertilizer.

Montalvo--The treatment plant in Montalvo discharges raw sludge to the Liquid Waste Treatment Facility, VRCSD, for treatment. The treated sludge is thickened in ponds and then hauled to a landfill.

Thousand Oaks-Olsen Road--The Thousand Oaks Olsen Road treatment plant aerobically digests sludge prior to lagooning and drying. After drying, the sludge is stockpiled on-site for disposal as necessary. Alternate sludge disposal involves hauling to a sanitary landfill when the on-site sludge storage capacity is reached.

Camarillo State Hospital--The Camarillo State Hospital treatment plant uses sun drying to dewater sludge. The sludge is stockpiled and made available for use as a fertilizer by employees of the hospital.

Moorpark--The treatment plant at Moorpark is a very small facility consisting of a septic tank and two oxidation ponds. The sludge from this facility is disposed of to nearby agricultural land.

In summary, two basic disposal methods are presently being utilized. At Oxnard and Ventura, sludge is or will soon be dewatered and then hauled to a Class I landfill. The remaining plants rely on private or public use of dried sludge as a soil amendment/fertilizer.

Characterization of Wastewater Sludges--

Five criteria were used to characterize municipal sludge. They were: moisture content, percent volatile solids, percent nitrogen, percent phosphorus, and calories/gram. Because of the difference in treatment and handling of the sludges prior to ultimate disposal, three categories characterized the wastes. These included:

1. Digested sludges that are dewatered by vacuum filtration. This would typify the practice anticipated at the Oxnard wastewater treatment plant.

2. Digested sludges that are dewatered by filter press. This is a characteristic of the proposed sludge handling facility for the Ventura treatment plant, which is scheduled to be in operation within the next few years.

3. Digested sludge that is then sun-dried. This is typical of the remaining plants. Characteristics of each class of waste are shown in Table 13.

TABLE 13. CHARACTERIZATION OF MUNICIPAL WASTEWATER SLUDGES

Characteristic	Digested sludge vacuum filter cake	Digested sludge filter press cake	Sun-dried
% Moisture	77.5	60	30
% Volatile Solids	60	60	40
% N	3.0	3.0	3.0
% P	2.5	2.5	2.5
Cal/gm (Dry solids)	2200	2200	1500

As shown in this table, the moisture content of the sludges is highest with digested vacuum filtered sludge and lowest with the sun-dried sludge.

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The percentage of volatile solids decreases from the vacuum-filtered sludge to the sun-dried sludge. Variations in nitrogen and phosphorus content are insignificant. Caloric content of the solids, important when considering incineration-type processes, is considerably lower for the sun-dried wastes.

Discussion of State and Federal Disposal Guidelines--

One major concern in the assessment of present disposal practices is the impact of possible State and Federal regulations governing uses of sludge. In the early stages of this project, a request was made to the California Department of Health for information relating to the current status and progress of regulations concerning disposal of sewage sludge on land. In response to our request, correspondence was received in January 1978 from the California Department of Health, Vector and Waste Management Section. The correspondence consisted of a copy of a progress report dated November 7, 1977. The report outlines the controversy involving the preparation of regulatory language concerning sludge disposal on land. It reviews the history of recent activities to sludge and its disposal to form a basis for understanding of the current regulatory situation.

In 1974, the Environmental Protection Agency distributed a review draft containing proposed numerical critieria to limit the amount of sludge-borne cadmium to be added to agricultural land. At that time, cadmium was considered to be the common chemical constituent of municipal wastewater sludge most likely to limit the extent to which sludge could be added to soil used to produce plant products to be eaten by humans. It was assumed that the EPA's numerical criteria would have adequate supporting rationale to adequately protect consumers of edible plant products raised in sludge treated soils.

By June of 1976, the EPA published guidelines in the Federal Register, which in the opinion of the California Department of Health, did not provide sufficient supporting rationale for adequate safeguards to protect the consumer from unhealthy intake of cadmium. Therefore, the California Health Department along with local and regional agencies, began looking for a rational number to use in developing regulatory critieria for sludge disposal on land. A working draft of the regulatory language concerning sludge disposal was prepared by November of 1976 and given to several large metropolitan sewage agencies for review, including those located in Los Angeles, Orange County, Sacramento, and the San Francisco Bay Area. After review of these agencies, the language in the 1976 draft was discarded.

In 1977, two committees were formed to provide consultation and to review working drafts. The first committee (Committee A) consisted of persons whose professions were oriented towards the perspective potential users of sewage sludge, such as soil scientists, representatives of the U.S. Department of Agriculture, representatives of the Federal Food and Drug Administration, California Department of Food and Agriculture specialists in fertilizer and feeds, soil scientists of the Central Valley Regional Water Quality Control Board, and a representative of the Food and Drug Section of the Department of Health.

The second committee (Committee B) consisted of persons representing producers and purveyors of waste materials such as members of the Regional

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Wastewater Solids Studies underway for the San Francisco area, the Sacramento metropolitan area, and the metropolitan areas of Los Angeles County and Orange County. Also included were a purveyor of sewage sludges and mixes containing sewage sludge and the Chairman of the Solids Waste Committee of the Metal Finishing Association of Southern California. Both committees were advised that the regulatory language did not include numerical criteria pertaining to chemical substances in the sludge which would govern the addition of sludge to agricultural land.

Several methods of controls are being considered. The first is control for projects on agency-owned land. This would apply in the cases where sewage sludge was applied to publicly owned land or land owned by the waste producer and would not be used to produce crops to be eaten by humans. In this proposed control, any contact between sludge constituents and edible portions of the crop would be unacceptable as would be the presence of sludge constituents on the surface of land grazed by animals providing a product to be consumed by humans. Sludge applied to soil that could be contacted by humans should have undergone composting or equivalent treatment or be injected so that soil free of sludge would cover the sludge. A chemical analysis of the wastewater discharge to a municipal wastewater treatment plant would be required so as to determine the necessity for chemical analysis of crops grown on land which received sludge treatment.

Plant products raised on sludge treated soil would not be sold or donated for consumption by humans if they have a cadmium concentration greater than twice that of plant products on the field plot on the same property that does not receive sludge. Land which is treated with sludge and later developed into R-1 or R-2 residential lots, must undergo covering with two feet of uncontaminated soil prior to subdivision. This can be accomplished by hauling in 2 feet of fill or by turning the soil over with a deep plow.

The second control method proposed by the California Department of Health is control for projects on privately-owned agricultural land. The owner of agricultural land would be given the results of field experiments representing the percent of uptake of cadmium by the greatest cadmium accumulated crop eaten by humans, for which he desires his soil to remain usable. These results would assure or give the farmer assurance that he would be able to produce crops that would not increase the amount of cadmium in the food marketplace and that he would be able to sell his crop in interstate commerce for consumption by humans if the FDA sets limits on cadmium in produce.

The third method of control regulated the transfer of custody of sludge. This control would limit transfer of sludge from the waste producers to persons that include only the following:

1. A person who complies with the regulations of the Department of Health pertaining to use and disposal of the sewage sludge and who is owner of land to which the sewage sludge would be added or a licensed landscape contractor.

2. Persons who receive the material in bags bearing the warning message in Item 3.

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3. Persons who sign a paper bearing the warning message, as follows:

"This material should not be added to soil that is intended to be used or usable for production of vegetables or fruits to be eaten by humans unless those vegetables or fruits are cited in a list published by the California Department of Health that indicates that the use of sludge on soil producing those items is acceptable."

4. Persons who market the material so that only people prescribed above receive it.

The report stated that regulatory language concerning sludge disposal would be forthcoming in 1978.

Present disposal practices in Ventura County, when viewed against proposed regulatory language, appear to have two areas of concern. First, most municipal wastewater sludges contain more than 20 mg/kg cadmium, making them undesirable for use on agricultural land. Additionally, pathogenic organism content will prohibit indiscriminant use because of high salmonella (10^3/gram) and ascaris ova (50/gram).

Agricultural Wastes

Discussion of Methodology--

A total of 38 agricultural processors and growers were interviewed during the course of the survey. All of the questions they were asked involved production quantities, waste solid quantities, and expected growth in the industry. The questioning followed the questionnaire form shown in Figure 40. Major agricultural processors were interviewed during the course of the survey, resulting in coverage of over 50 percent of the vegetable processors and 80 percent of the fruit and citrus processors which are the two major categories of waste producers for the county. This large sampling provided reliable information on the types of problems encountered with solid waste disposal and quantities involved. The survey was conducted on a person-to-person basis generally with the General Manager of Foreman in charge of the operation. Future projections were based on harvested area projections, waste production/crop production ratios, and crop production summaries from the County Agricultural Commission.

Production/Area--Figure 41 shows yearly vegetable/field crop production and harvested area in hectars between 1964 and 1976. Harvested area has ranged from a low of around 17,400 hectares to a high of about 22,200 hectares. This number fluctates from year to year and currently is at the 17,800 hectare level. Yearly production has varied between 363,000 and 617,000 metric tons per year. Current production is approximately 490,000 metric tons per year. Variations in production and harvested area are caused by a number of factors, most notably weather and crop prices. It is anticipated that harvested area may decrease in the future with increased residential development. Production is less predictable because of a shift in emphasis from low value crops to high value crops and increasing yield due to advances in technology.

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1. Interview Reference Number: ______________________________

2. Position of person interviewed: ______________________________

3. Date of interview: ______________________________

4. Interview category[1]: ______________________________

5. What is the production output? ______________________ (tons/year)

6. How is the waste produced (on a continuous or batch basis)? ______________________________

7. What, if any, analyses have been performed on the waste? If so, what is moisture content ______________, volatile content ______________, fertilizer value ______________, and BTU value ______________.

8. Are there any anticipated changes in composition expected over the next ten years? Discussion: ______________________________
____
____

9. What is the quantity of waste produced? ______________________

10. How is the waste presently disposed of? ______________________

11. What is the name of the contracting firm? ______________________

12. What cost is incurred in disposal of wastes? ______________________

13. What is the distance (round trip) to disposal site? ______________

14. What is the frequency of disposal? ______________________

15. What problems are found with present disposal method? __________
____

16. Are any changes anticipated? ______________________________
____

17. What alternative disposal methods have been used in the past?
____

[1] Category Key:

A = Municipal WWTP sludges
B = Animal manures
C1 = Vegetable packing wastes
C2 = Fruit packing wastes
D = Meat and fish processing wastes

Figure 40. Standard survey format.

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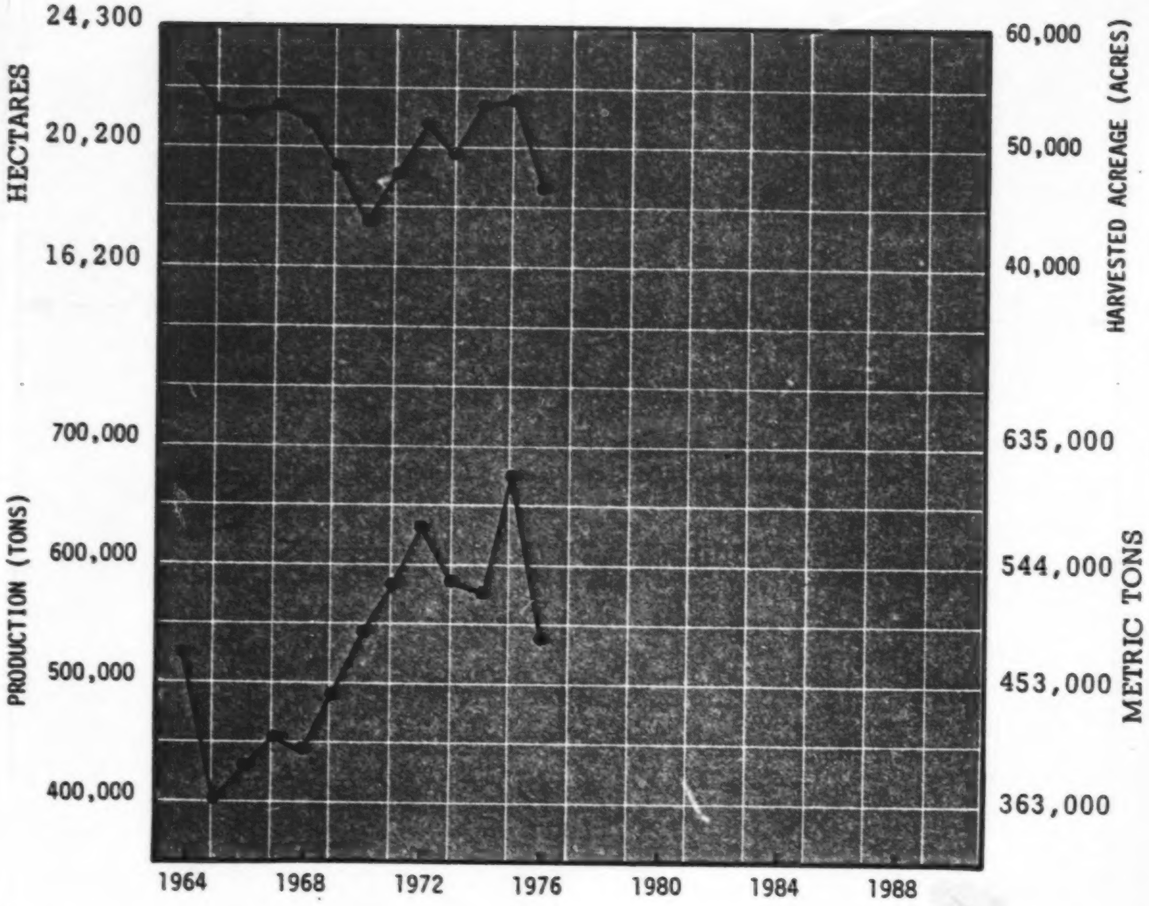

Figure 41. Vegetable field crop production and harvested area.

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TABLE 14. VEGETABLE/FIELD CROP WASTES

Reference No.	Total Production (Metric tons/yr)	Waste Production by Month (Metric tons) Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Waste (Metric tons)	Comments
7	4,305	204	204	204	204	204	204	204	204	204	204	204	204	2,449	Landfill, Ventura Refuse (7 days)
8	2,400	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	11	Bagged, sold to 4-H
9	870	36	36	36	36	36	36					36	36	290	Hauled to cattle by self, 6 days, 10 hrs.
10	5,375	109	109	109	109	109			30	60	60	114	109	918	Hauled to cattle by self
11	9,615	297	297	297	297	297				297	297	450	595	3,124	Hauled to cattle by self
12	1,495								8	8	8	8		32	Hauled to landfill by self
13	56,085	103	103	103	103			680	680	680	103	103	103	2,761	Hauled to cattle by self
14	15,715	529	529	529	529	529	529	27	27	27	529	529	529	4,842	Hauled to cattle by self
15	1,135	698	698	698	698	698	698	698	698	698	698	698	698	8,396	Includes process water, hauled to sheep, cattle
16									136	136	136			408	Hauled to landfill by self
17	1,700	25	25	25	25	25						25	25	175	Hauled to cattle by self
18	2,035	23	23	23	23	23	23	118	118	118	118	23	23	656	Hauled to cattle by self
19	81,020	172	172	344	344	381	36	36	36	72	72	209	209	2,083	Hauled to cattle by self
20	45,810	170	170	170	170					170	170	170	170	1,364	Sold as feed
21	1,535	775	775	775	775	775	775	775	775	1,682	1,682	775	775	11,114	Sold for fertilizer
22	45,010	590	590	590	590	590	590	590	590	590	590	590	590	7,080	Hauled to feed lots by others
23	13,610	326	326	163	102	106	4	4	54	109	54	326	326	1,900	Hauled to hog feed lot by others
24	26,090	72	72	72	72	72	72	72	1,660	3,248	3,248	72	72	8,804	To landfill by contractor
25	2,720									599	599	599		1,797	Hauled to cattle by self
26		136	136	136	136	136	136					680	680	2,176	Hauled to cattle by self
Total	288,135	4,266	4,266	4,275	4,214	3,902	3,104	3,205	5,017	8,699	8,569	5,612	5,145	60,380	
Total Waste Landfilled		276	276	276	276	276	276	276	2,008	3,596	3,596	284	276	11,693	

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Waste Summary (Survey)--The crop wastes determined by the survey are summarized in Table 14. Twenty food processors are shown in this summary form with each firm's name being designated by a confidential reference number. The first column in Table 14 shows total production in metric tons/year for each processor. This is followed by waste production by months for the months January through December and a total waste production for the year in metric tons. The comments listed in the last column describe present disposal methods. The bottom two rows of the table indicate total waste landfilled; i.e., the organic solid waste which is not used benefically but hauled to a landfill, and also the total waste production by month and by year. As shown in the table, waste constitutes approximately 20 percent of the total yearly production. The total waste hauled to a landfill represents only approximately 20 percent of the total waste produced. Vegetable/field crop waste production is centered in the Oxnard area.

Discussion of Disposal Methods--The major portion of vegetable solid waste is used as cattle feed. The transporation of waste to the feed operation is handled in a variety of ways. Some of the waste producers haul their own waste. In several cases, the feedlot operator transports the solid waste without compensation for either party. In other operations, waste producers are compensated to some degree for their waste product. Several larger processors paid to have their waste hauled, primarily to assure reliability. Waste is also used by hog farms and as fertilizer in isolated instances. The remainder of the waste products is hauled to landfill for disposal. Disposal costs run as high as $27.50/dry metric ton when the wastes are landfilled. Income derived through disposal was not available because of the competitive nature of the agricultural operations. Existing disposal practices have been followed for years, and stability is not a serious concern. Although some of the large waste producers incur some cost in disposal of their waste solids, the fact that 80 percent of the waste is being disposed of in a beneficial manner indicates that a major disposal problem does not exist.

Fruit Production and Waste--

Production/Area--Both annual production in metric tons and harvested area for citrus production between 1964 and 1976 are shown in Figure 42. As shown in this figure, production is highly variable operating on a cyclical basis with alternating high and low years. Production ranges between 481,000 and 789,000 metric tons/year. Production during 1976 was 572,000 metric tons/year. Area for citrus production was fairly constant due to the nature of the crop and varied between 18,200 and 21,800 hectares. The differences in production from year to year, due to the cyclic effect of citrus products and weather, may make a continuous disposal operation difficult to operate since substantial variations in waste loading would result.

Waste Summary (Survey)--The results of the waste production survey are summarized in Table 15. A total of 17 fruit producers and processors were interviewed. The table presents their total production in metric tons per year, waste production by month, and total annual waste production. The methods currently used for disposal of the waste solids are identified. The table also categorizes the waste into three groups: (1) landfilled waste, (2) total nonprocessed waste, and (3) total waste. A confidential reference number has

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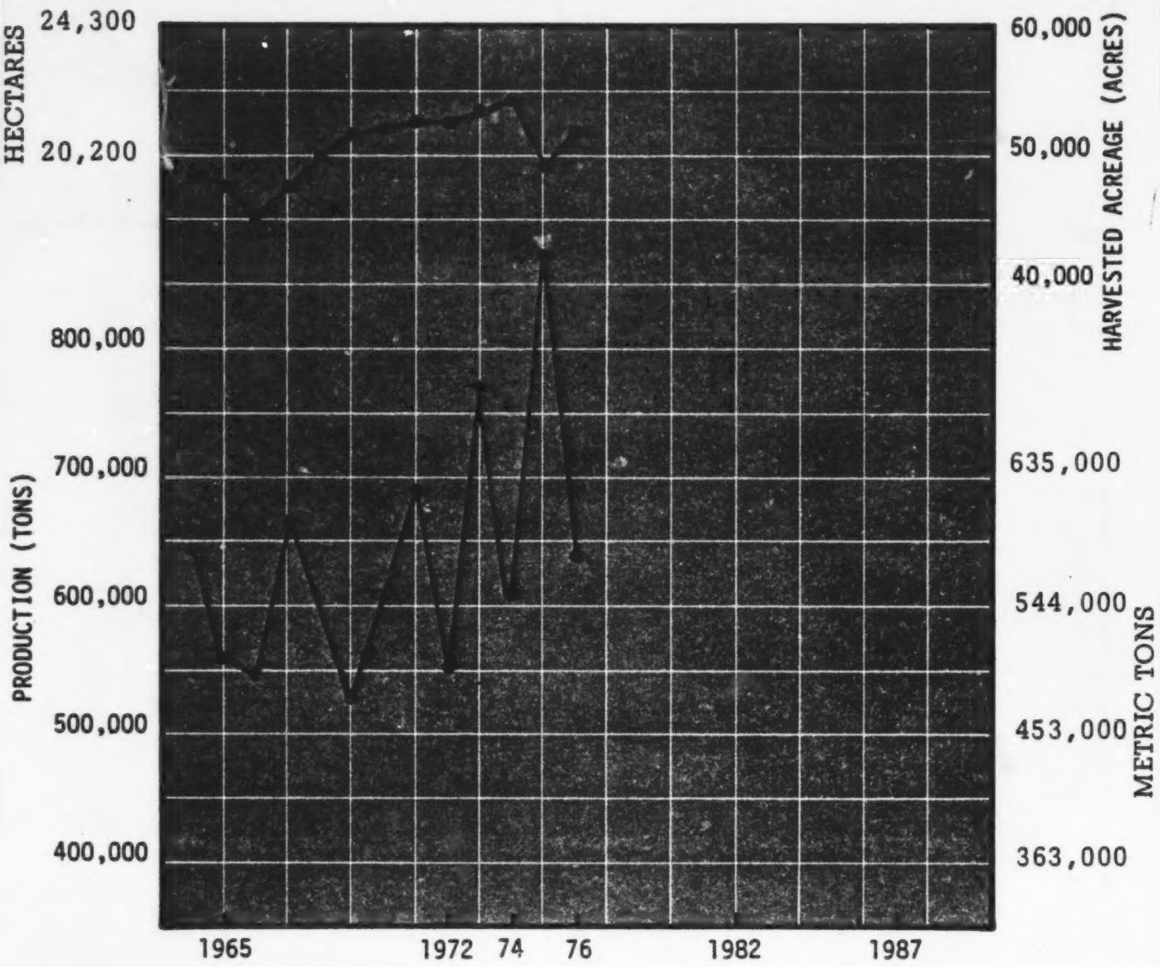

Figure 42. Citrus/fruit production and harvested area.

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TABLE 15. CITRUS WASTE SUMMARY

Reference No.	Total Production (Metric tons/yr)	Waste Production by Month (Metric Tons)												Total Waste (Metric tons)	Comments
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
28	23,585		76	76	76	76	76	76	76	76	76			684	Landfill, own truck, 5 days
29	14,060			27	27	27	27	27	27	27	27			216	Cattle, own truck, 5 days
30	28,010			100	100	110	100	100	100					600	Landfill, Harrison, 5 days
31	20,525					34	34	34	34	34	34			204	Cattle, own truck, 5 days
32	18,870	16	16	16	16	16	16	16	16	16	16		16	176	Hog, own truck, 5 days
33	22,680					68	68	68	68	68	68			408	Cattle, pig, Nova 5 days, $150/mo.
34	58,970	14	14	14	54	54	54	54	54	54	54			420	Landfill, own truck, 5 days
35	43,885	326	326	227	227	227	227	227	227	100	100	100	100	2,414	Dump, Harrison 5-1/2 days $450/mo.
36	34,020	23	23	23	23	23	23	23	23	23	23	23	23	276	Cattle, Walker 5 days $100/mo.
37	13,380	16	16	16	16	16	16	16	16	16	16	8		168	Landfill, Harrison $270/mo, 5 days
38	20,980	54	54	54	54	54	54	54	54					432	Landfill, Harrison, 5 days
39	136,090	136	136	136	136	136	136	136	136	136	136			1,360	Landfill, Harrison, 5 days Vent, Sat Fillmore
40	27,215	18	18	18	18	18	18	18	18	18	18			180	Landfill
41	27,215				4	4	4							12	Landfill
42*	2,395	100	100	100	100	100	100	100	100	100	100	100	100	1,200	Hogs, own truck
43*	77,110	4,990	4,990	4,990	4,990	1,630	1,630	1,630	1,630	1,630	1,630	4,990	4,990	39,720	Pectin waste
Total	568,980	5,693	5,769	5,797	5,841	2,583	2,583	2,579	2,579	2,298	2,298	5,221	5,229	48,470	
Non-processed		565	640	640	685	685	685	682	682	401	401	108	100	6,274	*Firm involved in fruit processing
Total Non-processed waste		604	680	707	752	854	854	851	851	570	570	131	139	7,563	

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been used to identify individual producers. Approximately 80 percent of the total waste results from fruit processing operations. As shown in the yearly totals, the landfilled waste constitutes only 15 percent of the total waste generated from fruit production. The remaining 85 percent was used in some beneficial manner.

Discussion of Disposal Methods--Of the 48,100 metric tons of citrus fruit waste produced a year, over 80 percent is used in the manufacture of additional products. Although the production is done outside Ventura County, the waste product was included in the summary because the future stability of the current practice cannot be completely assured. As shown on the bottom of the summary, the total landfilled waste accounts for 6,300 metric tons or approximately 15 percent of the total waste production. The remainder of the waste is hauled to cattle and hog feedlots. Wastes are hauled to landfills or feedlots either by the producer or by a private trucking firm hauling at some fixed fee per month.

Agricultural Waste Production Summary--

Present Production/Area--Figure 43 presents total yearly agricultural production and harvested area between 1964 and 1976. Yearly production ranges from 0.86 to 1.4 million metric tons. Production in 1976 was 1.05 million metric tons. The production is cyclical in nature because of variations in fruit production. The harvested area varies from 38,800 to 97,000 hectares. The 1976 area is approximately 89,800 hectares.

Present Waste Quantities--An agricultural waste summary is shown in Table 16. Fruit wastes and vegetable field crop wastes are summarized in this table. Daily averages are given in kilogram/day for both total and landfilled wastes on both wet and dry bases. Total waste quantities were extrapolated from surveyed waste quantities using a ratio of actual production to surveyed production. In the case of fruit production, the number presented represents an average of high or low years. In the case of vegetable/field crop wastes, it was assumed that 20 percent of production is field packed, resulting in no waste. The moisture content of the waste product was assumed to be 85 percent. Yearly averages in metric tons per year are also shown. The percentage landfilled in each situation is also presented. All categories are totalized to provide total agricultural waste production.

Area/Projections--In the development of projections of future waste production levels, the primary variable considered was the change in area that might result from increased residential development. The Regional Land Use Program has estimated that under the worst cases of low density development, a maximum of 12,800 hectares might be taken out of production between 1975 and the year 2000. This reduction would correspond to a maximum of 5,100 hectares being taken out of production within ten years. If high-density development were undertaken, acreage taken out of production could be as low as 490 hectares. Area taken out of production would then represent between 1 and 13 percent of total acreage, depending upon the type of development pursued. This uncertainty coupled with the possibility of improved yields through advances in technology resulted in the conclusion that present production levels will also be representative of production levels ten years in

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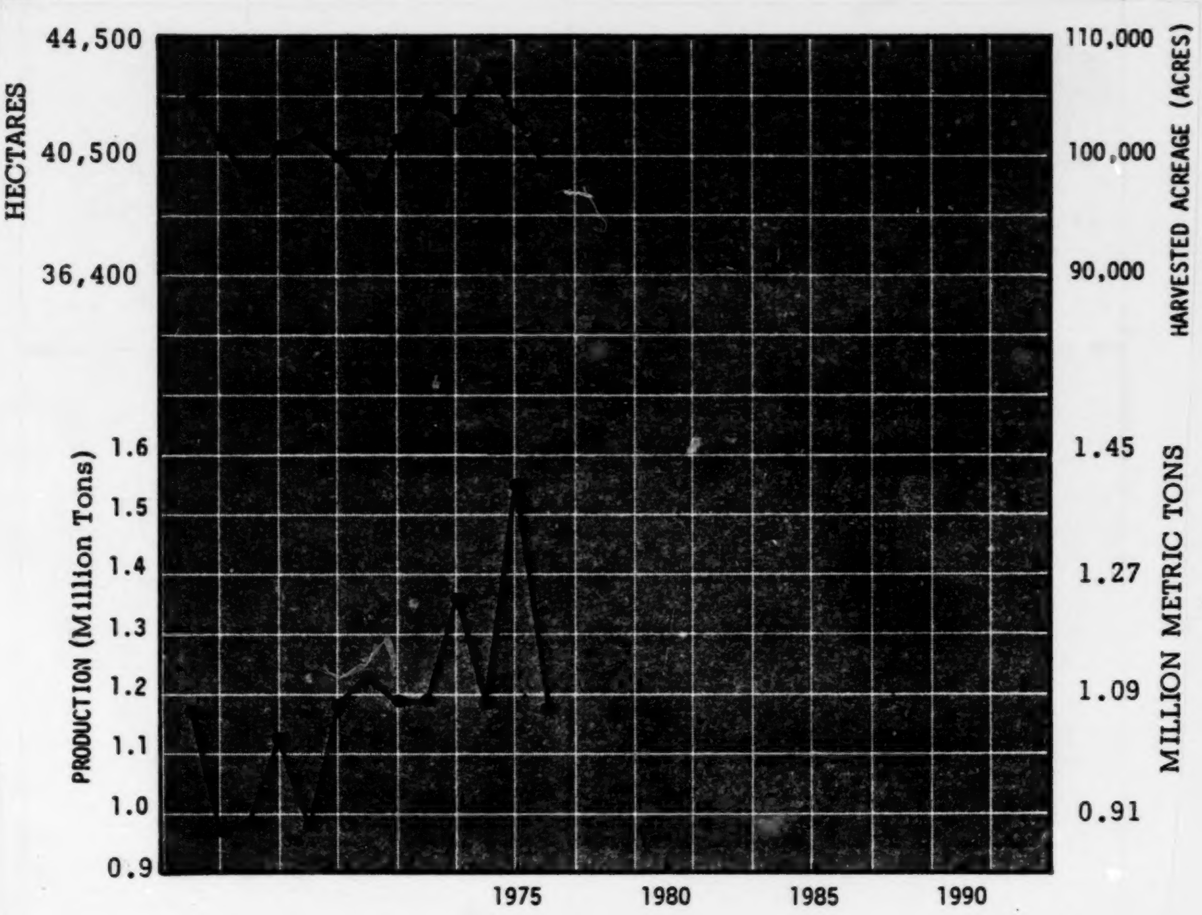

Figure 43. Total agricultural production and harvested area.

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TABLE 16. AGRICULTURAL WASTE SUMMARY

Item	Daily Average (Kg/day) Present Dry Weight	Daily Average (Kg/day) Landfill Dry Weight	Daily Average (Kg/day) Present Wet Weight	Daily Average (Kg/day) Landfill Wet Weight	Yearly Average (metric ton/year) Present Dry Weight	Yearly Average (metric ton/year) Landfill Dry Weight	Yearly Average (metric ton/year) Present Wet Weight	Yearly Average (metric ton/year) Landfill Wet Weight	% Landfilled
Citrus/ Fruit	24,085	3,120	160,510	22,140	8,790	1,110	58,585	7,689	13
Vegetable/ Field Crop	38,015	7,370	253,440	49,110	13,875	2,690	92,505	17,925	19
Total	62,100	10,490	413,950	71,250	22,665	3,800	151,090	25,510	17

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the future. It is not anticipated that variations would total more than 5 percent.

Characterization of Wastes--As shown in Table 17, the agricultural wastes are characterized by moisture content, percentage nitrogen and phophorus, and calories per gram. The values indicated in the table are considered a composite of fruit and vegetables and do not characterize every type of fruit and vegetable.

TABLE 17. CHARACTERIZATION OF AGRICULTURAL WASTE

% Moisture	85
% N	.7
% P	1.1
Cal/gm	3300

Animal Manures

Discussion of Methodology--

Four major sources of animal manure in Ventura County were identified. They include a dairy, a cattle feedlot, and two chicken ranches. When interviewing these livestock operations, questions focused on size of the operation, total waste production, characterization of the waste, and the method in which they disposed of the waste. The Standard Survey Format was used. In all instances, the above information was obtained. However, data pertaining to income derived from the sale of manure products was unavailable from two of the sources. It is assumed that the producers were afraid of disrupting their market.

Waste Summary (Survey)--

The animal manure waste summary is shown in Table 18. In this table, the four firms are listed by confidential reference number. Approximately 80 percent of the total animal manure waste produced was from poultry operations. The remainder of the animal manure was from either dairy or cattle feed lot operations.

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TABLE 18. ANIMAL MANURE WASTE (SURVEY)

Reference number	Metric tons/mo	Comments
3	1,500	9,000 cattle, sold for citrus fertilizer
4	1,000	2,000 dairy cows, sold for use as fertilizer
5	10,200	Manure dried and solid as cattle supplement
6	3,400	Manure sold for use as fertilizer
	16,100	

Characterization of Waste--

The animal manure waste characterization data are found in Table 19. This table gives characteristics for the three different types of animal manures. The wastes are characterized by five different characteristics: (1) percentage of moisture, (2) percentage of volatile solids, (3) percentage of nitrogen, (4) percentage of phosphorus, and (5) calories per gram.

TABLE 19. ANNUAL MANURE CHARACTERIZATION

Characteristic/source	Dairy	Feedlot	Poultry
% Moisture	90	30	65
% Volatile Solids	80	80	40
% N	4	3.6	5
% P	0.5	0.5	2
Cal/gm	3330	3300	1800

Discussion of Disposal Methods--

All of the animal manure produced by the four operations is sold and put to use in some beneficial manner. The cattle feedlot manure is sold as a citrus fertilizer. The income derived from this sale is unknown.

The dairy operation sells its manure to a company which uses the manure along with other waste products to form a compost which is then sold to the general public or to landscapers for fertilizer. The income from this sale is minimal, but the dairy operator is assured of reliable service and does not have to commit manpower for disposal purposes.

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Chicken manures are dealt with in two ways. A percentage of the manure is dehydrated by a natural gas drying operation to approximately 10 percent moisture, then it is sold as a cattle supplement. The remainder is sun-dried to a moisture content of around 30 percent and then sold for its fertilizer value.

Present and Projected Quantities--

The animal manure summary shown in Table 20 gives the present and projected waste quantities for both poultry and livestock manure. Present quantities are shown in both dry and wet values in metric tons per month. Present waste production levels were developed utilizing livestock production quantities obtained from the Agricultural Commissioner. A small percentage of total livestock production is not represented by the four major sources. Projected values are shown on a dry and wet basis also in metric tons per month. A total in the last row is given for each category.

TABLE 20. ANIMAL MANURE SUMMARY

	Present		Projected	
	Metric tons/mo (dry)	Metric tons/mo (wet)	Metric tons/mo (dry)	Metric tons/mo (wet)
Poultry	4,760	13,600	5,240	15,000
Livestock	1,540	3,060	1,540	3,060
Total	6,300	16,660	6,780	18,060

Meat/Fish Processing Wastes

Discussion of Methodology--

There exists very few meat and fish processing operations in Ventura County. Meat processing operation is on a small scale only in the Saticoy area and was not considered to warrant additional study. Those interviewed were located in Oxnard and were solely involved in the packing and processing of sea urchin. Two of these operations were surveyed. The waste product generated by these operations is sea urchin shell which cannot be specifically labeled as an organic waste product. The shell is a solid waste product from a fish processing operation, however, and was included during the course of the survey.

Waste Summary (Survey)--

The survey of the two fish processing operations in Oxnard is summarized in Table 21. The two firms produced similar waste products (sea urchin shells and spines) and together generate a total of 450 metric tons per year of waste.

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TABLE 21. MEAT/FISH PROCESSING WASTE (SURVEY)

Reference number	Quantity	Disposal Method
45	360 metric tons/yr	Landfill
46	91 metric tons/yr	Landfill

Discussion of Disposal Methods--

Fish processing wastes are landfilled. The City of Oxnard hauls containers of the sea urchin shells to the Santa Clara landfill for disposal for a unit cost per load.

Organic Waste Summary

Present and projected waste quantities were developed based on survey information. Present disposal practices were identified, and certain wastes were assigned problem status.

Present and Projected Wastes Quantities and Locations--

A summary of present and projected waste quantities is presented in Table 22. The four different types of wastes, (1) agricultural, packing, and processing waste, (2) animal manure, (3) municipal sludge, and (4) meat/fish processing waste, are shown on the far left column of this table. Quantities of these wastes are given for both a present and ten year projected time period. Waste quantities are presented on both a wet and dry basis and are categorized as total and problem waste. Waste quantities are presented on both a daily and yearly average. The problem waste refers to that portion of the total waste which has no beneficial use.

The locations of the producers of these wastes are shown in Figures 45 and 46. In Figure 45 a combination of municipal wastewater plants producing sludge, vegetable/field crop waste producers, fruit waste producers, and animal manure producers are shown relative to their scale of operation. The key on the right side of the page defines relative levels of waste production per year. Most of the solid waste producing operations are located within a 5-mile radius of Oxnard.

In Figure 46, the locations of organic wastes hauled to landfill are shown. These wastes can be characterized as problem wastes since they do not serve any beneficial purpose to either the producer or the recipient of the waste. Four landfill sites are located on this map. Santa Clara and Toland Road are both Class II landfills. Ventura Coastal is a private landfill, and Simi is a Class I landfill. The Simi Valley landfill is the only landfill which can currently accept wastewater sludges with a solids content of less than 25 percent and hazardous wastes.

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TABLE 22. ORGANIC WASTE SUMMARY

Type of Waste	Units	PRESENT Total Waste (Wet)	PRESENT Total Waste (Dry)	PRESENT Total Prob. Waste (Wet)	PRESENT Total Prob. Waste (Dry)	10 YEAR PROJECTION Total Waste (Wet)	10 YEAR PROJECTION Total Waste (Dry)	10 YEAR PROJECTION Total Prob. Waste (Wet)	10 YEAR PROJECTION Total Prob. Waste (Dry
Agric. Packing & Processing	Metric tons/yr	176,600	22,660	25,510	3,830	151,090	22,660	25,510	3,830
	Metric tons/day	414	62	70	11	414	62	70	11
Animal Manures	Metric tons/yr	199,625	75,660	-	-	216,363	81,375	-	-
	Metric tons/day	547	208	-	-	592	223	-	-
Municipal Sludge	Metric tons/yr	37,570	14,050	37,570	14,050	54,575	21,305	54,575	21,305
	Metric tons/day	102	38	102	38	149	58	149	58
Meat/Fish Processing	Metric tons/yr	454	-	454	-	454	-	454	-
	Metric tons/day	2	-	2	-	2	-	2	-

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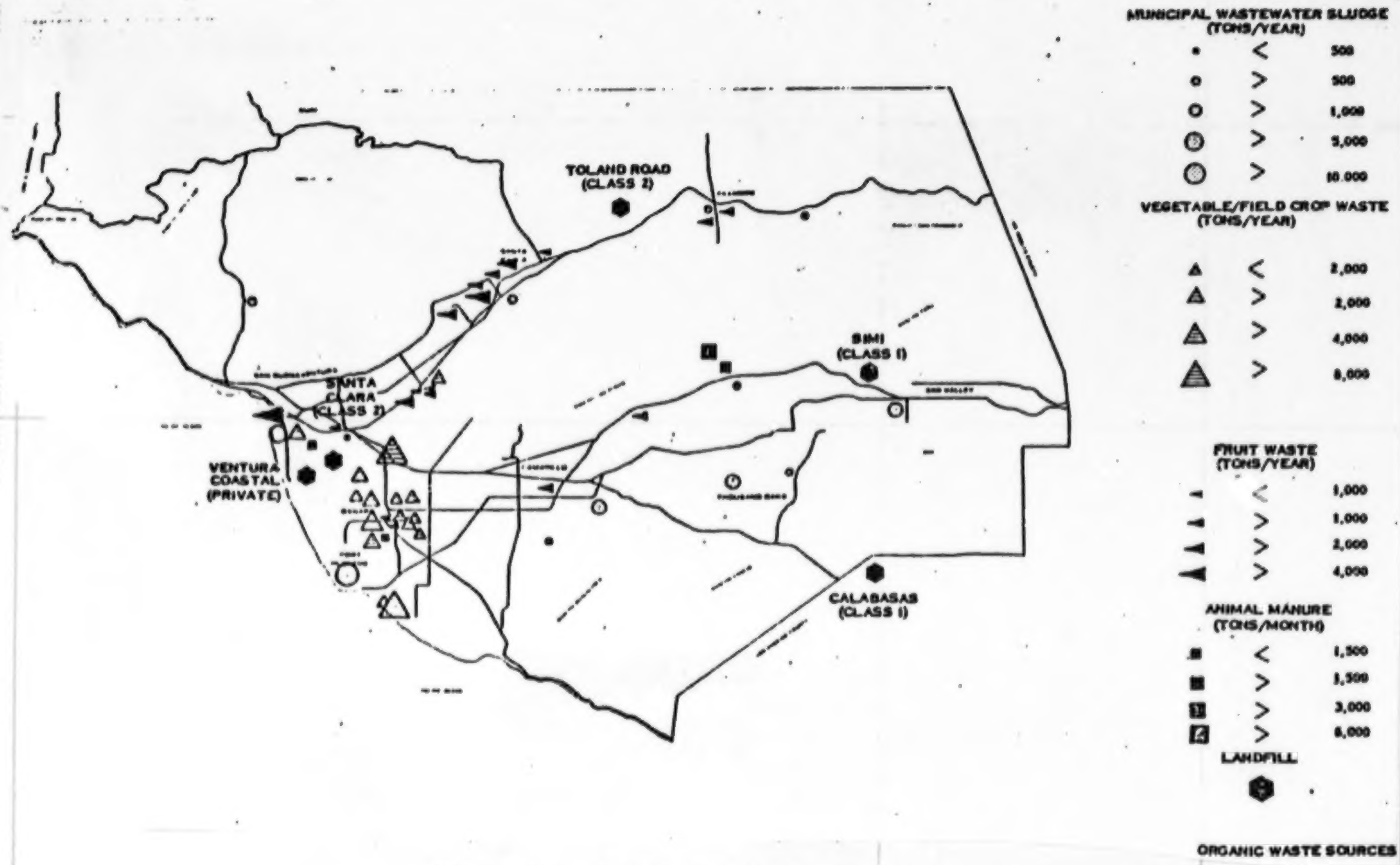
MUNICIPAL WASTEWATER SLUDGE (TONS/YEAR)
< 500
> 500
> 1,000
> 5,000
> 10,000
VEGETABLE/FIELD CROP WASTE (TONS/YEAR)
< 2,000
> 2,000
> 4,000
> 8,000
FRUIT WASTE (TONS/YEAR)
< 1,000
> 1,000
> 2,000
> 4,000
ANIMAL MANURE (TONS/MONTH)
< 1,500
> 1,500
> 3,000
> 6,000
LANDFILL
ORGANIC WASTE SOURCES
TOLAND ROAD (CLASS 2)
SIMI (CLASS I)
SANTA CLARA (CLASS 2)
VENTURA COASTAL (PRIVATE)
CALABASAS (CLASS I)

Figure 44. Organic waste sources.

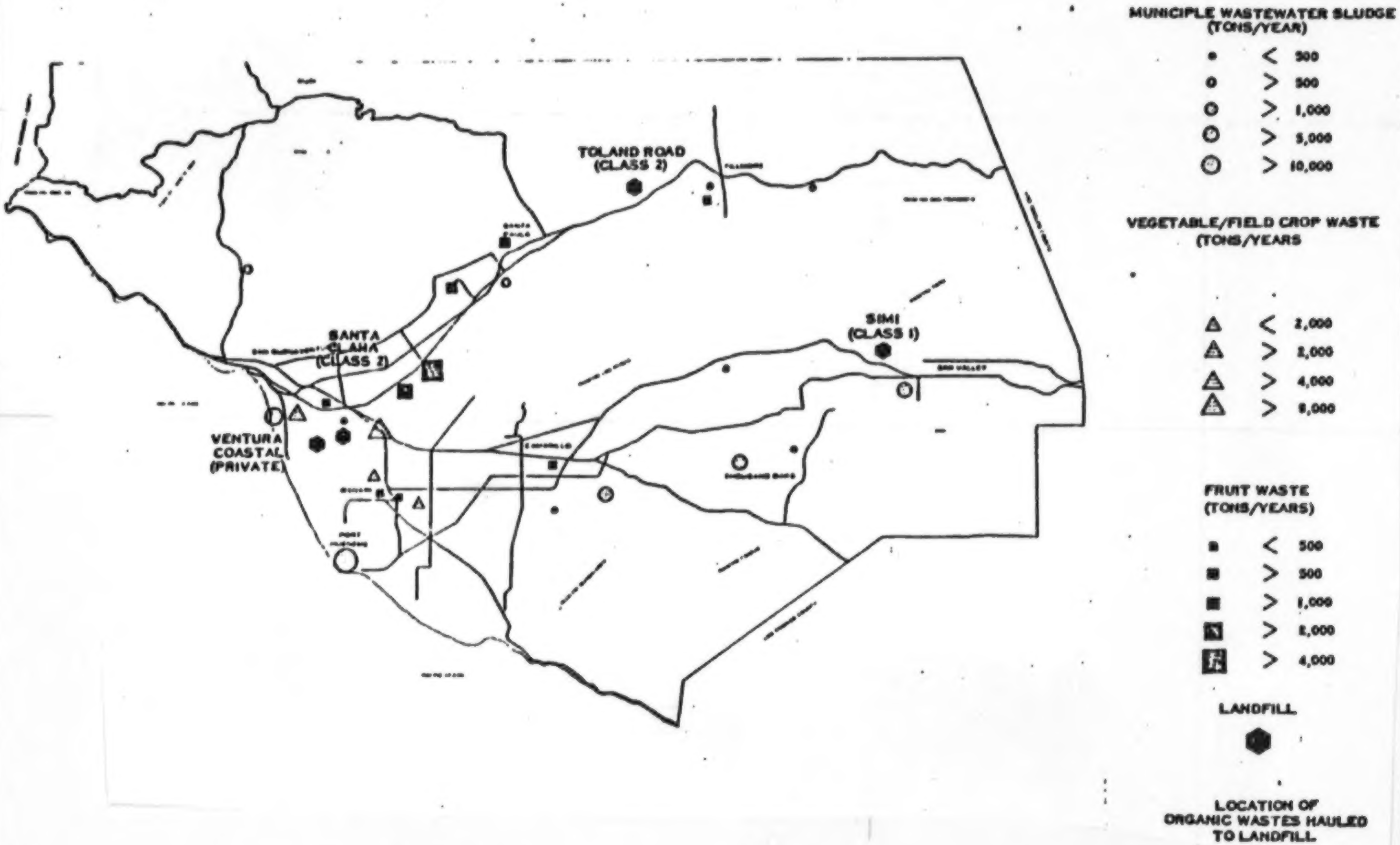
TOLAND ROAD (CLASS 2)
SIMI (CLASS 1)
SANTA CLARA (CLASS 2)
VENTURA COASTAL (PRIVATE)
MUNICIPLE WASTEWATER SLUDGE (TONS/YEAR)
< 300
> 300
> 1,000
> 5,000
> 10,000
VEGETABLE/FIELD CROP WASTE (TONS/YEARS
< 2,000
> 2,000
> 4,000
> 8,000
FRUIT WASTE (TONS/YEARS)
< 500
> 500
> 1,000
> 2,000
> 4,000
LANDFILL
LOCATION OF ORGANIC WASTES HAULED TO LANDFILL

Figure 45. Location of organic wastes hauled to landfill.

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Present Disposal Practices and Problems--

As indicated earlier, approximately 80 percent of the vegetable waste and 85 percent of the fruit waste are presently disposed of in a manner which benefits the producer and the recipient of the waste. These wastes are hauled to livestock feed operations or used in some method of fertilizer application. Wastewater sludges are handled by a number of methods. The major producer of sludge (the Oxnard treatment facility) will soon dewater digested sludge and truck the resultant dried cake to the Simi Valley landfill, Class I disposal site, for disposal. Other treatment plants use sludge drying beds to dewater or dry the sludge to a low moisture content and allow farmers and other people to have access to that sludge for free pick up. The City of Ventura wastewater treatment plant as well as the Oak View treatment plant disk the sludges into an area adjacent to the plant. These disposal methods will not be feasible if presently drafted regulations on sludge disposal on land are released. Animal manures are currently being handled in a beneficial manner and present no significant problems. The producers of these wastes are deriving income from the sale of the waste, and no real problem exists. Meat and fish processing wastes are produced in an insignficant quantity; therefore, the current practice of landfilling appears to be the most effective.

Assignment of Problem Status--

Problem solids are those which are not presently handled in a beneficial manner. All sewage sludges are considered to be problem solids based on the assumption that the presently drafted regulations concerning sludge disposal will be issued. There will probably need to be an alternate means for disposing of these sludge solids in the near future.

Problem waste also includes a percentage of vegetable and fruit processing waste solids that are not currently being recycled or marketed. Of the two waste solids, the municipal wastewater treatment plant sludges are considered to be the most significant problem because of the greater quantities and health risks present.

ANALYSIS OF ALTERNATIVES

This section reviews procedures and assumptions that were used in the analysis of alternative systems for the handling of organic wastes. Criteria were developed to assist in the comparison of alternatives. Economic and environmental considerations were studied and an apparent best alternative selected.

Alternative Analysis Criteria

In the analysis of structural and nonstructual alternatives, a set of criteria was developed to allow equal comparison. Sizing criteria were developed for use in the evaluation of alternatives, based on information obtained in the survey regarding waste quantities produced and disposal methods presently employed. These criteria are presented in Table 23 and represent quantities of "problem waste" produced in Ventura County. All wastewater sludge was considered to be a problem because of the uncertainty surrounding sludge disposal requirements. In the analysis of alternatives, sludge quantities from Oxnard, Ventura, and Camarillo were used because of the short distances

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separating those plants facilitating central processing. These three plants will present approximately 70 percent of sludge production within the County. If structural alternatives prove feasible for the best case assumption, outlying plants might also be incorporated. Agricultural waste quantities presented represent that fraction of waste that is landfilled. Animal manure and meat/fish processing wastes were not found to be a problem and are being handled in a near optimum fashion.

TABLE 23. SIZING CRITERIA - COMPARISON OF ALTERNATIVES

Waste Source	Present (metric tons/day) Dry	Wet	Projected (metric tons/day) Dry	Wet
A. Municipal Sludge	24	82	35	115
B. Agricultural	11	70	11	70
C. Combination	35	152	46	185

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Description of Alternatives

Six potential alternative treatment/management systems were identified and analyzed. Four of the alternatives were structural solutions while two were considered nonstructural in nature. A screening of alternatives was conducted, eliminating several solutions. The concept of establishing an organic waste brokerage was discarded after initial review because of uncertainty surrounding sludge disposal guidelines and a concern about interfering in the market structure of agricultural operation. An advertising campaign was also elminated as a possible alternative because of its uncertain impact on private markets. Land application of sludges was also eliminated from further consideration because of sludge disposal guidelines. The structural solutions included incineration, pyrolysis, composting, and heat drying. The nonstructural solutions consisted of trucking the wastes and no project. Each alternatives was analyzed on the basis of three different types of feed material: sewage sludge only, agricultural waste only, and a combination of two. Costs were then developed for each system with each type of feed material. Additionally, environmental impacts were then identified and quantified.

Incineration--Incineration, or thermal processing, reduces the waste volume and sterilizes the solids. The liquid content is greatly reduced through evaporation. As a result, the quantity of waste to be finally disposed is greatly reduced.

The most common types of incinerating systems are the multiple-hearth and fluidized-bed furnace. In most systems, the sludge is first dried and then burned, producing an inert ash as a final waste product. Excess air can then be preheated and injected into the incinerators so that there is enough oxygen for combustion to occur. Odors from effluent gases are generally not a problem in incinerators, because the odoriferous materials are burned off inside the incinerators. Also, incineration may be a self-sustaining

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system if sufficient fuel value is present in the waste. In sewage sludges, moisture content should be between 30 and 40 percent solids (50 percent volatile) for a self-sustaining system. When a supplemental fuel is needed, conventional fossil fuels are used.

Pyrolysis--The pyrolysis process is the physical and chemical decomposition or organic matter brought about by the action of heat in a reactor where oxygen is limited. Heat is applied to the solid waste to distill the volatile compounds. Because there is only a limited amount of oxygen in the system, complete combustion of the volatile and carbonaceous material does not occur. During the pyrolysis cycle, the heat applications induce a reaction with water and carbon dioxide which results in carbon monoxide. The predominant products from the pyrolysis process are hydrogen, carbon monoxide, methane, carbon dioxide, various hydrocarbons, steam, ferrous metals, and glass. In considering pyrolysis as a treatment/disposal system, it should be noted that the process development has been relatively recent, and its performance is, therefore, uncertain.

Composting--Composting is the aerobic decomposition of organic waste by microorganisms. The process considered would be a two-step operation. First, the waste would be placed in small piles, and air would be drawn through each pile to force-ventilate the waste. This would continue for approximately two to three weeks to allow destruction of pathogenic organisms. Once this phase was complete, the waste would then be windrowed and turned daily by a composting machine to facilitate drying. The two stages are essential to adequate processing. A windrow operation alone would not assure adequate pathogen destruction. Also, the force-ventilated system would not provide adequate drying without the additional processing. Once dry, the product would then possibly be marketed as a soil supplement. Major disadvantages of this alternative are the high requirement for land, extensive site preparation, and relatively short equipment life.

Heat Drying--In heat drying, hot gases are used to evaporate the water content of sludge leaving a dried sludge which can be used as a fertilizer and, in the case of agricultural waste, as animal feed. Usually, however, the drying system is coupled with an incineration system in which the dried sludge is burned to ash. If incineration is used, heat for drying the sludge is generated from the combustion process. If incineration is not used, all the heat for drying must be produced from outside fuels.

High fuel costs, fuel scarcities, and air pollution are major disadvantages of heat drying sludge without subsequent incineration. Part of the fuel costs can be offset by selling the dried sludge as a soil conditioner. However, the marketability of heat dried sludge has not been proved for the Ventura County area. It is generally not a reliable product due to texture and other characterisitcs of the sludge.

The great degree of uncertainty surrounding future fuel prices encourages caution when suggesting heat drying as a viable alternative. The energy intensive process may prove too costly to operate in future years.

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Centralized Trucking--Currently, municipal wastewater sludges are being handled by a number of different methods. Trucking the sludge to a landfill is one of the current solutions to the problem. Disposal to land on-site is a second approach, while sun-drying and free distribution to the local community is another solution used by smaller communities in the area. Trucking is directly involved in the disposal of the agricultural waste, either to cattle feedlots, hog feedlots, to the field for disking under, or to landfill sites for disposal. In any of these methods of disposal, some means of hauling becomes necessary.

From this discussion of current disposal methods, it becomes clear that trucking is not a new solution to the solid waste disposal problem in Ventura County. The nonstructural solution of centralized trucking does provide a different approach to the problem. The current trucking practice consists of a number of independent operations. A centralized trucking scheme would provide coordination of a major trucking hauler or haulers in the disposal of municipal sludges, agricultural wastes, or a combination of the two. This coordination could be accomplished by either the outright buying of trucks and operation and maintenance of those trucks by VRCSD or by the leasing of such trucks from an independent company and coordination of their operation by VRCSD. It might be expected that by using such a large-scale operation, over-all operation and maintenance costs will be reduced to each waste producer.

No Project--With no project, current disposal practices would continue. Implementation of State Health Department sludge disposal regulations as presently drafted might make this alternative untenable. Heavy metal and pathogenic organism limitations might prohibit the current disposal practices.

In general, agricultural wastes are being dealt with in a beneficial manner. A no project alternative would not violate any proposed regulations, nor would it have significant impact on the industry. Of primary concern is whether present agricultural waste disposal practices are economical when viewed against other alternatives.

COMPARISON OF ALTERNATIVES

In the comparison of alternatives, environmental and economical considerations were weighed equally to determine the apparent best alternative. Environmental impacts and costs associated with the various alternatives were detailed.

Environmental Impact Matrix

Environmental factors such as air quality, water quality, aesthetics, and others contibute to the overall acceptability of any given alternative. These environmental factors are of equal importance as cost comparison when selecting the best alternative. To simplify the process of comparing alternatives, an environmental impact matrix was constructed. The alternatives appear on the vertical axis, while the environmental considerations are listed on the horizontal axis. The impact each alternative has on the environmental factors is evaluated against the reference baseline of a pristine environment.

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The environmental impact matrix is shown in Table 24.

The environmental impact matrix shown in Table 25 quantifies the impact associated with each alternative for wastewater sludges. The alternatives are listed on the vertical axis, and environmental impacts are shown on the horizontal axis. The alternatives are quantified on the basis of impact with the value of 1 representing the least impact and the value of 5 representing the greatest impact. The alternative with the least impact has the lowest overall total.

Table 25 shows that centralized trucking has the least impact when considering wastewater sludges. A table for agricultural and a combination would be identical except that no project and centralized trucking would have comparable impacts when considering agricultural wastes.

Cost Matrix

Cost estimates have been developed for each of the four structural alternatives and the two nonstructural alternatives for three cases. The first case is for municipal sludge, the second case is for agricultural solids waste, and the third case for a combination of municipal sludge and agricultural solid waste. The sizing criteria for comparison of these alternatives are shown in Table 23. Quantities of solids for these three cases on both a wet and dry basis are shown for present and projected years. These numbers were used to size the structural and nonstructural alternatives for determination of project cost. Relevant data and assumptions for the individual alternatives are as follows:

Incineration and Pyrolysis

1. ENR = 3000 (Construction Cost Index)
2. Capital costs amortized at 8%, 15 years, Capital Recovery Factor = 0.11683
3. Fuel costs = 33% of O&M costs for wastewater sludges and combined wastes
   = 75% of O&M costs for agricultural wastes
4. Manpower = 58% of O&M costs for wastewater sludges and combined wastes
   = 20% of O&M costs for agricultural wastes

Composting

1. ENR = 3000 (Construction Cost Index)
2. Capital costs include site preparation
3. a) $1.5 x 10^6 have 5-year life, 8% interest, Capital Recovery Factor=0.25046

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b) Remaining $150,000 has 20-year life, at 8% interest, Capital Recovery Factor = 0.10185

4. Fuel cost = 8% of O&M cost

5. Manpower = 85% of O&M budget, $25,000/man/year

Heat Drying

1. ERN = 3000 (Construction Cost Index)

2. Capital costs amortized at 8%, 15 years, Capital Recovery Factor = 0.11683

3. Fuel costs = 60% of O&M for wastewater and combined, 66% for agricultural wastes

4. Manpower = 25% of O&M, $25,000/man/year

Centralized Trucking

1. Costs based on leasing cost of $35/hr; savings might be realized through competitive bidding

A cost matrix summarizing costs associated with the different alternatives is shown in Table 26. Costs are presented in ranges for the various alternatives owing to the variability found in reported costs throughout the literature. The low end costs for heat treatment, incineration, and pyrolysis represent estimates of the lowest cost possible for each of the alternatives. High-range composting costs presented were developed based on actual experience in composting operations. A review of the literature has shown that lower costs have been reported. Estimated total cost is shown for each alternative for each of the three fuel materials. Operation and maintenance costs and total costs on a dollars per dry metric ton basis are also shown. Costs of trucking to the site are not shown for the structural alternatives. The anticipated range for that operation is between $5.50 and $11 per metric ton. These costs were not included so that they might act as a credit against potential revenue for the finished product in the case of heat drying and composting. Revenue is uncertain but is expected to be less than $11 per metric ton.

Total costs for handling wastewater sludge ranged from a low of $22 to a high of $79 per metric ton. Capital and operating costs were similar for the incineration, pyrolysis, and heat drying systems as expected. Composting capital and operating costs were substantially lower; however, useful life for other structural alternatives. Costs for the no project alternatives are based on leasing of vehicles by individual agencies. Those costs are higher than continuing present practices, a policy that would most likely be impossible with the issuance of sludge disposal guidelines.

Centralized trucking of wastewater sludges offers the most cost-effective solution to the waste disposal problem. This is based on the assumption that

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TABLE 24. ENVIRONMENTAL IMPACT MATRIX

	Alternative	Water Quality	Air Quality	Aesthetics (Noise, Odors, Etc.)	Wildlife & Vegetation	Resources	Land Use
Structural Solutions	1a) Incineration (1) WWTP sludges (2) Agricultural wastes (3) Sludges and agricultural wastes	Incineration will not have an impact on water quality, but may show positive impact on water quality over previously used alternatives.	Emissions from stack have negative impact on air quality with increasing magnitude from (1) to (3).	Odors may occur in the immediate vicinity of facility with increasing magnitude from (1) to (3).	Damage to vegetation and wildlife may occur as the result of increases in air pollution in the vicinity of the project.	The use of auxiliary fuels is required if solids input moisture content exceeds 70%. Case (2) has the highest moisture content in raw form.	The actual process requires little land, however an "environmental" buffer zone may be needed to minimize the nuisance of odors and air pollution.
	1b) Pyrolysis (1) WWTP sludges (2) Agricultural wastes (3) Sludges and agricultural wastes	Pyrolysis will not have an impact on water quality	The air-starved process of pyrolysis produces limited emissions in theory, but may impact air quality if operated at less than optimal conditions.	Potential odor problems exist in such a process. Proper operation would minimize the problem.	Air pollution and/or odor problems may cause a change in the wildlife and vegetation in the area surrounding the project.	The gases produced in pyrolysis are recycled to maintain the high temperatures required. Auxiliary fuels will be needed for startup.	Minimal land requirement for process site. Buffer zone recommended to minimize odor and air pollution problems.
	1c) Composting (1) WWTP sludges (2) Agricultural wastes (3) Sludges and agricultural wastes	Runoff from composting site could interfere with surface or groundwater quality. Proper operation of site would minimize this problem	Limited to emissions from trucks to and from composting site. Actual operation would not affect air quality. Localized odors.	Odors may be present depending on the nature of the sludge, i.e. raw, digested, act. and the freshness of the agricultural wastes	Land required for the site may cause a shift in natural habitat for some wildlife. Impact will increase from (1) to (3).	Fuel required by machinery used to turn and transport compost material.	Land requirements of 40 - 60 acres are necessary for this process. Flat land is preferred.
	1d) Heat Drying (1) WWTP sludges (2) Agricultural wastes (3) Sludges and agricultural wastes	No impact	Air quality impact associated with burning of fuel to facilitate drying. Some volatilization of organic solids in drying process.	Odors generated by volatilization of organic solids in drying process.	Odors and air pollution problems may affect wildlife and vegetation in the project vicinity.	Auxiliary fuel is required for drying, increasing in quantity required from Case (1) to (3).	Minimal land requirements. Buffer zone may become necessary depending on operational status.
Non-Structural Solutions	2a) Centralized Trucking (1) WWTP sludges (2) Agricultural wastes (3) Sludges and agricultural wastes	No impact providing sludges are disposed of to a Class I site where groundwater is protected from seepage.	Emissions from trucks to and from landfill sites.	Increased vehicular noise on trucking routes. Odors along routes as a result of exhaust emissions.	Minimal impact will occur. Slight increase in vehicular traffic over established routes will not significantly affect wildlife and vegetation.	Fuel for trucks transporting solids to landfill will be required.	Landfill sites require considerable land acreage to accommodate dumping site and buffer zone area.
	2b) NO PROJECT (1) WWTP sludges (2) Agricultural wastes (3) Sludges and agricultural wastes	Sludge currently disposed of to land may damage underlying groundwater quality.	Current hauling practices contribute to air pollution.	Odor problems from current land disposal operations will continue.	Minimal impact.	Fuel for current trucking practices.	Current disposal sites will require expansion to accommodate increased quantities of solids.

Reference Baseline – – – Pristine Environment.

TABLE 25. ENVIRONMENTAL IMPACT MATRIX FOR WASTEWATER SLUDGES

Alternative	Water Quality	Air Quality	Aesthetics	Wildlife & Vegetation	Resources	Land Use	Total
1a - Incineration	1	5	4	3	4	3	20
1b - Pyrolysis	1	4	4	3	3	3	18
1c - Composting	2	2	3	3	2	5	17
1d - Heat Drying	1	5	4	2	5	3	20
2a - Centralized Trucking	1	2	2	2	2	4	13
2b - No Project[a]	5 / 1	2 / 2	3 / 2	1 / 2	1 / 2	4 / 4	16 / 13

1 = least impact
5 = greatest impact

[a] The split box represents the two implications of a no project decision. The left half shows the no project alternative impact if the proposed State guidelines for sludge disposal are enacted and prohibit current practices. The right half shows the no project alternative impact if regulations are not enacted and current practice of individualized disposal continues.

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TABLE 26. ALTERNATIVE COST MATRIX

Process	Wastewater Sludges			Agricultural Wastes			Combination		
	Capital Cost $\$ \times 10^6$	O&M Costs \$/dry ton[a]	Total Cost \$/dry ton[a]	Capital Cost $\$ \times 10^6$	O&M Costs \$/dry ton[a]	Total Cost \$/dry ton[a]	Capital Costs $\$ \times 10^6$	O&M Costs \$/dry ton[a]	Total Cost \$/dry ton[a]
Incineration	2.6-3.2	20-31	44-61	2.6-3.2	47-56	121-149	4.8-6.0	21-30	55-72
Pyrolysis	2.6-3.2	18-24	42-55	2.7-3.3	33-40	112-138	4.8-6.0	20-28	54-69
Composting	1.3-1.7	11-14	33-42	1.5-1.9	19-24	64-82	2.4-3.0	13-17	46-53
Heat Drying	3.7-4.5	31-39	65-79	2.1-2.6	88-110	150-187	5.0-6.0	36-45	72-88
Centralized Trucking	-	-	22	-	-	43	-	-	25
No Project	-	-	25[b]	-	-	28[c]	-	-	-

[a] Metric ton.

[b] No project costs for wastewater sludges based on independent disposal costs.

[c] Present disposal cost for problem agricultural wastes.

sludge disposal guidelines will prohibit existing practices. The savings realized through a centralized trucking system should be greater than 15 percent over independent trucking. Reduced administrative costs could increase savings further.

Costs for treatment and disposal of agricultural wastes were considerably higher because of the increased moisture content present. Costs ranged from $64 to $187 per metric ton. Costs for centralized trucking were higher than present disposal costs, because many of the waste producers produce relatively small quantities of wastes. This would make it necessary for trucks to stop at several locations to pick up wastes, thus increasing nonproductive time. Most waste producers already own disposal vehicles and operate them very inexpensively. The fact that existing disposal requirements are less expensive than others will not present a conflict as it would in the case of sludge disposal practices. Agricultural wastes were not deemed a major problem and existing practices are acceptable.

Systems operating on combined wastes do not offer any real economic advantages when compared with lowest cost alternatives operating on wastewater sludges or agricultural wastes alone.

Selection of Apparent Best Alternatives

Based on environmental and economic considerations, it appears that a centralized trucking operation would be the best means to handle the wastewater sludges. This recommendation, however, is heavily dependent on the actual implementation of sludge disposal guidelines. It appears that implementation is near certain. If, however, guidelines are not issued, it would be most attractive to continue existing practices.

Agricultural wastes are presently being handled in near optimum fashion. Over 85 percent are being utilized benefically. The remaining 15 percent are being disposed of in a very economical manner. No project is therefore needed.

APPARENT BEST ALTERNATIVES

Municipal Wastewater Sludges

As explained under the section, Selection of Apparent Best Alternatives, a centralized trucking operation would be the best means to handle the wastewater sludges and the factors set forth in the first paragraph of that section apply directly to municipal wastewater sludges.

The centralized trucking alternative could be operated in two methods. The first method would be to lease the trucks from a reliable trucking company and provide service to the 13 wastewater treatment plants on a scheduled basis. The advantage of a centralized trucking scheme in this situation would be a sharing of the operation and maintenance costs between the various treatment plants and a built-in reliability factor based on the number of trucks involved in the process. The Ventura Regional County Sanitation District would be involved on a management-type level coordinating the operation of sludge disposal from the various plants. The process of leasing these trucks

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would remove the VRCSD from the responsibility of operating and maintaining these vehicles. The second method would be for the VRCSD to purchase these trucks and take the responsibility of operation and maintenance of the vehicles. This method incurs considerable capital outlay and a greater responsibility on the part of the VRCSD. An overall savings may be seen for this method of approach, however, the flexibility of a leasing arrangement is not present. Leasing allows individual communities and VRCSD to react as necessary upon issuance of sludge disposal guidelines.

The cost of such a management scheme, as was shown in the alternative cost summary, is $22/metric ton on a dry basis for wastewater sludges. This cost is based on a leased trucking schedule with the trucks costing $35/hour and a disposal cost of $2.75/metric ton. This cost is based on hauling to the current Class I landfill site in Simi Valley which presently has a life of approximately 7 years. It is noted that there is a site adjacent to the Simi Valley landfill site which is currently under consideration for development as a Class I landfill. If development occurs, it would extend the life of the Class I site in that area to approximately 15 years. If the sludge was hauled to a location farther from the treatment plants than Simi Valley, the cost would be increased accordingly; however, this possibility is somewhat remote. Based on the projected cost of the alternatives, the centralized trucking cost is approximately half the nearest low cost alternative, excepting "No Project."

Agricultural Wastes

Agricultural wastes are presently being handled in near optimum fashion. Over 85 percent are being utilized benefically. The remaining 15 percent are being disposed of in a very economical manner. No project is therefore needed.

IMPLEMENTATION

It is recommended that no action be taken until sludge disposal guidelines are issued. At that time, if present practices are not acceptable, competitive bids should be sought for a long-term basis, most probably one year. It is anticipated that actual rates will be well below the P.U.C. rate of $35/hour due to competitive market pricing.

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